Product Innovation in Sustainability-Oriented New Ventures

A Process Perspective

Duygu Keskin
PhD Thesis

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To my parents

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Summary

The role of innovation in bringing about the necessary change for the sustainability of the planet and future generations is widely acknowledged among academia and practice. Sustainable innovations require organizations to design and develop new products, services and markets that transform the current practices in society while both decreasing environmental impact and increasing social welfare. Within the context of sustainability and business, new firms are increasingly recognized as candidates of creating innovations necessary for sustainability. Sustainability is an inherently uncertain journey into the future and entrepreneurial action is driven by uncertainty. Despite this recognition, little is known on how new ventures actually engage in this journey. How does the entrepreneurial context influence the decision-making in relation to new product development and sustainability? What are the implications of sustainability motivation for the innovation process? How the product innovation process unfolds within entrepreneurial settings motivated by an issue related to sustainability is the central question of this study.

New ventures are certainly not miniatures of large organizations. They possess distinct organizational settings and decision-making processes. On the one hand, they are seen to be more advantageous in innovation due to their flexible decision-making process, which enables them to quicker respond to the dynamics of industry environment. On the other hand, they are confronted with high levels of uncertainty associated with liabilities of being new and small. New ventures often do not possess the resources and capabilities necessary for bringing innovations to the market. Furthermore, in the case of sustainable innovations they face the challenge of demonstrating and justifying the sustainability benefits of new products to customers and stakeholders. Considering these challenges, new ventures are often not able to identify a promising product-market combination at the outset of the product innovation process, and instead progressively define their business idea. The objective of this exploratory study is to gain a profound understanding of this process: (1) How can the product innovation process in new ventures be described? (2) What explains the similarities and differences among the product innovation processes of new ventures? (3) How does the sustainability motivation of the entrepreneurs influence the product innovation process?

Chapter 2 of this thesis reviews the product innovation literature in order to understand how the product innovation process in new ventures can be described. On the basis of varying degrees of innovativeness in literature, developing new radical products that challenge existing practices are selected as the focus of this study. Radical innovations are inherently more uncertain in comparison to incremental innovations due to their newness to the customers and to the firms engaged in this process. Therefore, a firm's ability to introduce radically new products requires not only technological but also marketing skills, knowledge and capabilities. Furthermore, in the case of new ventures, uncertainties also stem from a lack of resources and capabilities to engage in costly product development processes. Considering these challenges, the product innovation process in new ventures is conceptualized as an iterative learning process of uncertainty reduction, driven by a series of design experiments. By engaging in a series of design experiments, firms learn progressively about

the limitations and possibilities of particular product-market ideas. Design experiments enable firms to progressively define the product-market pair based upon information learned.

In Chapter 3, entrepreneurship literature on opportunity identification and decision-making is reviewed. The dichotomy of causation-effectuation has been selected as an interpretive lens to explain similarities and differences in the product innovation processes of new ventures. This dichotomy combines the rational decision-making theories with new theoretical perspectives, which define an emergent organic process view. Various factors are identified that are likely to influence the product innovation process; such as entrepreneurial expertise, the resource position of firms and the level of entrepreneurs' perceived uncertainty. Subsequently, Chapter 4 reviews the literature in the emerging field of sustainable entrepreneurship, where the motivation of sustainable entrepreneurs is identified as the most crucial factor that distinguishes them from commercial entrepreneurs. This study suggests that the individual and combined effects of these factors explain the similarities and differences of product innovation processes in sustainability-oriented new ventures.

To fully understand how new ventures translate sustainable product ideas into new businesses, a process-oriented research approach is adopted with a focus on the relationships between key concepts identified in literature. In chapter 5, these key concepts are used to develop a descriptive model of the product innovation process in new ventures that are motivated by an issue related to sustainability. This model suggests that the definition of a product-market pair is driven by two distinct activities: design experiments and stakeholder interactions. Accordingly, the innovation process is conceptualized based upon three variables: (1) product-market goals, (2) design experiments, and (3) stakeholder interactions. Moreover, the product innovation processes in new ventures show similarities and differences along these three variables. Thereby, a conceptual model is proposed to explain the similarities and differences among new ventures' product innovation processes based upon the variables of the descriptive model as well as the factors identified in literature. Consequently, propositions are formulated to predict the influence of these factors on the decisions concerning product-market combinations and the type of actions entrepreneurs engage in. Four sustainability-oriented new ventures are selected as cases for the purpose of: (1) literal replication in order to explain similarities, and (2) theoretical replication in order to predict contrasting results. The data is gathered from both interviews and complementary documents provided by the case companies and web articles. Three of the four cases were followed and interviewed between 2009 and 2013. An additional case was subsequently selected to allow for sufficient contrast with earlier ones, and has been followed between 2012 and 2013. This study employs case descriptions and theoretical propositions as the two main data analysis strategies in guiding the case study research and analysis.

Chapter 6 presents a historical account of the case firms' product innovation processes based on the descriptive model proposed. These case histories describe the rationale behind each firm's engagement in design experiments as well as stakeholder interactions and their outcomes. The case study shows that firms engage in design experiments and stakeholder interactions for various reasons including: testing technical feasibility and market viability of particular product-market combinations, demonstrations, getting the commitment of stakeholders and generating initial revenues. Furthermore, the evolution of product-market definitions, the type, sequence and timing of design experiments and stakeholder interactions show variable patterns. The case firms are analyzed to explain why and how they engaged in various product-market ideas, design experiments and stakeholder interactions.

Chapter 7 presents a cross-case analysis in which the cases are analyzed and compared according to the factors, as suggested in the conceptual model, as well as patterns predicted through propositions in Chapter 5. The role of these factors in explaining the similarities and differences in product innovation processes is discussed. The level of technical uncertainty appears to influence the type of action that drives the definition of product-market pair. The level of expertise and the availability of resources are likely to influence the intensity and duration of product-market iterations a firm engages with. The outcome of design experiments and stakeholder interactions appear to influence the entrepreneurs' perception of uncertainty and consequently their approach to product-market development. The sustainability motivation is also likely to influence the duration of product-market iterations. Finally, the product innovation processes of the case firms are analyzed in order to identify patterns of product-market iterations. The analysis shows that the case firms vary on the basis of focus and flexibility in their definition product-market pair, and consequently in terms of the number and duration of product-market iterations they engage over time. In addition, the analysis reveals that the periods of focused development alternates with periods of flexible development. Furthermore, this chapter tests propositions formulated in Chapter 5 based upon case study evidence.

Chapter 8 presents the conclusions and recommendations of this study. The main findings of this research include: (1) a descriptive model to describe the product innovation process in new ventures, (2) a conceptual model to explain the similarities and differences among the product innovation process in new ventures, and (3) insights into how sustainability motivation of entrepreneurs influences the product innovation process. The descriptive model is useful for reconstructing the product innovation process by representing the product-market iterations pursued as well as design experiments and stakeholder interactions engaged over time. The conceptual model suggests that the interplay of various factors help explain similar and different patterns of the product innovation process, as well as the drivers, timing and frequency of design experiments and stakeholder interactions. On the basis of these different patterns, two distinct approaches to product-market development are identified: (1) adaptive approach; characterized by a focus on a specific product-market pair early on, experimenting with it for several years and adapting the pair based on design experiments and stakeholder interactions, and (2) exaptive approach, characterized by a flexible attitude towards the product-market pair, the instrumental use of design experiments in generating new options, and a strong focus on stakeholder interactions. While an adaptive approach is pursued for the purpose of converging product-market ideas, an exaptive approach is pursued for exploring alternative options and is therefore divergent. In

addition, the findings of this study suggest that sustainability motivation is likely to escalate the commitment of entrepreneurs to a particular product-market pair unless justifying sustainability benefits for alternative market segments, at least in entrepreneurs' mind, is relatively easy. Finally, Chapter 8 presents a number of recommendations aimed at product innovation and entrepreneurship theory, particularly focusing on the further testing of the conceptual model and reformulated propositions.

The findings of this research contribute to a better understanding of product innovation processes in new ventures. This study provides entrepreneurs, particularly novices, design practitioners and students who are considering starting a new venture based on a sustainable product idea with relevant new insights. In particular, they concern understanding the different type of decision-making logics and their implications for the product development process. Insights into this process can support firms in using different approaches simultaneously and interchangeably, both during the innovation process over time and under different conditions of uncertainty. This enables them to engage in design experiments and stakeholder interactions with different purposes more effectively. Finally, this study recommends new ventures to combine their strong vision for sustainability with affordable small steps in order to create room for experimentation and increase learning effects in relation to sustainability.

Summary in Dutch

Samenvatting

De rol van innovatie in het teweeg brengen van de noodzakelijke veranderingen om zorg te dragen voor de duurzaamheid van onze planeet en toekomstige generaties wordt algemeen onderkend door zowel academici als mensen uit de praktijk. Duurzame innovaties vereisen van organisaties dat ze nieuwe producten, diensten en markten creëren die de huidige handelswijze in de samenleving veranderen, en tegelijkertijd de milieu-impact verminderen en het maatschappelijk welzijn verhogen. In de context van duurzaamheid en het bedrijfsleven, worden nieuwe ondernemingen steeds meer erkend als de aangewezen kandidaten voor het creëren van innovaties die nodig zijn voor duurzame ontwikkeling. Echter, duurzaamheid is inherent aan een onbestendige reis naar de toekomst, en de daarbij noodzakelijke ondernemersactiviteiten worden gedreven door onzekerheid. Ondanks deze onderkenning, is er weinig bekend over de wijze waarop nieuwe ondernemingen daadwerkelijk deelnemen aan deze reis. Hoe beïnvloedt de ondernemerscontext de besluitvorming met betrekking tot de ontwikkeling van nieuwe producten en duurzaamheid? Wat zijn de gevolgen van de duurzaamheidsmotivatie voor het innovatieproces? Hoe ontvouwt het productinnovatieproces zich in een ondernemende omgeving die gemotiveerd is door duurzaamheidsidealen? Dat is de centrale vraag van deze studie.

Nieuwe ondernemingen zijn zeker niet miniatuur versies van grote organisaties. Ze beschikken over een andere organisatorische setting en besluitvormingsprocessen. Aan de ene kant worden ze in het voordeel gezien bij innovaties vanwege hun flexibele besluitvorming, die hen in staat stelt om sneller te reageren op de dynamiek van de maatschappelijke context. Aan de andere kant worden ze geconfronteerd met een hoge mate van onzekerheid in verband met hun nieuwheid en kleinschaligheid. Nieuwe ondernemingen bezitten vaak niet de middelen en capaciteiten die noodzakelijk zijn voor het op de markt brengen van innovaties. Bovendien, in het geval van duurzame innovaties, worden ze geconfronteerd met de uitdaging om de duurzaamheidsvoordelen van de nieuwe producten aan te tonen en te rechtvaardigen tegenover klanten en stakeholders. Gezien al deze uitdagingen, zijn nieuwe ondernemingen vaak niet in staat om al aan het begin van het productinnovatieproces veelbelovende product-marktcombinaties te identificeren, maar in plaats daarvan definiëren ze hun business idee meer geleidelijk. Het doel van deze verkennende studie is om een diepgaand begrip van dit proces te krijgen: (1) Hoe kan het productinnovatie proces in nieuwe ondernemingen worden beschreven? (2) Wat verklaart de overeenkomsten en verschillen tussen productinnovatieprocessen van nieuwe ondernemingen? (3) Op welke wijze heeft de duurzaamheidsmotivatie van de ondernemers invloed op het productinnovatieproces?

Hoofdstuk 2 van dit proefschrift bespreekt de productinnovatie literatuur met als doel te begrijpen hoe het productinnovatie- en ontwerpproces in nieuwe ondernemingen kan worden beschreven. Aan de hand van de verschillende gradaties van innovativiteit in de literatuur, is de ontwikkeling van nieuwe radicale producten die bestaande praktijken uitdagen geselecteerd als het object van studie voor dit proefschrift. Radicale innovaties zijn inherent onzekerder in vergelijking tot incrementele innovaties vanwege hun nieuwheid voor zowel de markt als de bedrijven die betrokken zijn bij dit proces. Derhalve vereist dit van een bedrijf de vaardigheid om nieuwe radicale producten succesvol te introduceren, niet alleen in technologische zin, maar ook qua kennismanagement, design, marketing en productie. Bovendien, in het geval van nieuwe ondernemingen, stammen onzekerheden verder voort uit een gebrek aan middelen en mogelijkheden om deel te nemen in kostbare productontwikkelingsprocessen. Gezien deze uitdagingen, wordt het productinnovatieproces in nieuwe ondernemingen hier opgevat als een iteratief leerproces gericht op het verminderen van onzekerheden, aangestuurd door een reeks van ontwerpexperimenten. Door zich te engageren in een reeks van ontwerpexperimenten, leren de bedrijven geleidelijkerwijs de beperkingen en mogelijkheden van specifieke product-markt-ideeën. Ontwerpexperimenten maken het voor bedrijven mogelijk om geleidelijk de product-markt combinatie te definiëren, gebaseerd op de opgedane informatie.

In hoofdstuk 3, wordt de ondernemerschapsliteratuur met betrekking tot de identificatie van kansen en besluitvorming besproken. De tweedeling tussen causal-effectual is geselecteerd als een interpretatieve lens om de overeenkomsten en verschillen in het productinnovatieproces van nieuwe ondernemingen te beschrijven. Deze tweedeling combineert de rationele besluitvormingstheorieën, met een accent op de oorspronkelijke doelen, en nieuwe theoretische perspectieven, die de nadruk leggen op het proces van het ontstaan van ideeën. Verschillende factoren zijn geïdentificeerd die vermoedelijk het productinnovatieproces beïnvloeden, zoals expertise in ondernemerschap, de middelen die ter beschikking staan aan de bedrijven en het niveau van de door de ondernemers gepercipieerde onzekerheid. Daaropvolgend wordt in hoofdstuk 4 de literatuur over het opkomende onderzoeksgebied van duurzaam ondernemen behandeld, waarbij de motivatie van duurzame ondernemers wordt geïdentificeerd als de meest cruciale factor die hen onderscheidt van commerciële ondernemers. Deze studie suggereert dat individuele en gecombineerde effecten van deze factoren de overeenkomsten en verschillen van de product-innovatie processen in op duurzaamheid gerichte nieuwe ondernemingen verklaren.

Om volledig te begrijpen hoe nieuwe ondernemingen duurzame productideeën vertalen in een business, een proces georiënteerde aanpak is geadopteerd met een focus op de verhoudingen tussen sleutelbegrippen geïdentificeerd in de literatuur. In hoofdstuk 5, worden de sleutelbegrippen uit de literatuurverkenning gebruikt om een beschrijvend model van het product innovatieproces in nieuwe, op duurzaamheidsgerichte ondernemingen te ontwikkelen. Het model suggereert dat de definitie van de product-markt combinatie wordt gedreven door twee onderscheidende activiteiten: ontwerpexperimenten en interacties met stakeholders. Dienovereenkomstig wordt het innovatieproces geconceptualiseerd op basis van drie variabelen: (1) product-markt doelen, (2) ontwerp-experimenten, en (3) stakeholder interacties. Bovendien toont het productinnovatieproces in nieuwe ondernemingen gelijkenissen en verschillen vanuit het perspectief van deze drie variabelen. Daaropvolgend wordt een conceptueel model voorgesteld om de overeenkomsten en verschillen tussen de productinnovatieprocessen in nieuwe ondernemingen te verklaren aan de hand van de variabelen van het beschrijvend model en de factoren uit de literatuur. Zodoende worden stellingen voorgesteld om de invloed te voorspellen van de factoren op de beslissingen met betrekking tot product-markt combinaties en het type acties waarin ondernemers zich engageren. Hierna zijn vier door duurzaamheid gedreven nieuwe ondernemingen geselecteerd als empirische cases met als doel: 1) letterlijke replicatie om gelijkenissen te verklaren, en 2) theoretische replicatie om contrasterende resultaten te voorspellen. Met het conceptuele model als inhoudelijke basis, zijn vervolgens de benodigde empirische gegevens verzameld door middel van interviews. Ook zijn aanvullende documenten verschaft door de case bedrijven en case specifieke artikelen geraadpleegd van het internet. In drie van de vier gevallen zijn de bedrijven gevolgd en geïnterviewd tussen 2009 en 2013. Een extra, vierde case is vervolgens geselecteerd om voor voldoende contrast te zorgen met de eerdere cases en is gevolgd tussen 2012 en 2013. Deze studie maakt daarbij gebruik van case beschrijvingen en theoretische proposities als de twee belangrijkste data-analyse-strategieën.

Hoofdstuk 6 presenteert een historische beschrijving van productinnovatieprocessen van de case bedrijven aan de hand van het eerder gepresenteerde beschrijvende model. De case histories beschrijven de rationale achter de betrokkenheid van de bedrijven bij de ontwerp-experimenten en de stakeholders interacties en de resultaten daarvan. De case studie toont aan dat bedrijven betrokken raken in ontwerpexperimenten en interacties met stakeholders vanwege verschillende redenen, waaronder: het testen van de technische en commerciële levensvatbaarheid van specifieke product-markt combinaties, demonstraties, het verkrijgen van commitment van stakeholders en het genereren van initiële inkomsten. Bovendien tonen de evolutie van de product-markt definities, het type, de volgorde en de timing van de ontwerpexperimenten en stakeholders interacties variabele patronen. De case bedrijven zijn geanalyseerd om te verkennen en te verklaren waarom en hoe ze zich engageerden in de verschillende product-markt-ideeën, ontwerpexperimenten en interacties met stakeholders.

Hoofdstuk 7 presenteert de cross-case-analyse waarin de bedrijf cases worden geanalyseerd en vergeleken aan de hand van de factoren van het conceptuele model alsook de patronen voorspeld door middel van proposities in hoofdstuk 5. De rol van deze factoren in het verklaren van de overeenkomsten en verschillen in het productinnovatie proces wordt besproken. Het niveau van technische onzekerheid lijkt vooral het type actie te beïnvloeden dat de product-markt combinatievorming bepaalt. Het niveau van expertise en de beschikbaarheid van middelen lijken de intensiteit en de duur van de product-markt-iteraties waarin het bedrijf zich engageert te beïnvloeden. De uitkomsten van de ontwerpexperimenten en interacties met stakeholders lijken de onzekerheidsperceptie en derhalve hun aanpak van de ontwikkeling van product-markt combinaties te beïnvloeden. Tenslotte lijkt de duurzaamheidmotivatie de duur van product-markt iteraties te beïnvloeden. Ook zijn de productinnovatieprocessen van de case bedrijven geanalyseerd om patronen van product-markt-iteraties te identificeren. Uit de analyse blijkt dat de case bedrijven variëren in hun focus en flexibiliteit bij de definitie van product-markt-combinaties, en zodoende ook in termen van het aantal en de doorlooptijd van product-markt-iteraties waarmee zij zich bezighouden over de tijd. Daarnaast, blijkt uit de analyse dat de periodes van gerichte ontwikkeling afgewisseld worden met periodes van flexibele ontwikkeling. Tenslotte worden de eerder in hoofdstuk 5 voorgestelde proposities getest, gebaseerd op de bevindingen van de case studie.

Hoofdstuk 8 presenteert de conclusies en aanbevelingen van dit onderzoek. De belangrijkste bevindingen van het onderzoek zijn: (1) een beschrijvend model om het productinnovatieproces in nieuwe ondernemingen te beschrijven, (2) een conceptueel model om de overeenkomsten en verschillen tussen het product innovatieproces in nieuwe ondernemingen te verklaren, en (3) inzichten in hoe de duurzaamheidsmotivatie van ondernemers het productinnovatieproces beïnvloedt. Het beschrijvende model is handzaam voor de reconstructie van het productinnovatie proces door de representatie van de nagestreefde product-markt-iteraties en ontwerpexperimenten en interacties met stakeholders over de tijd. Het conceptuele model suggereert dat het samenspel van de verschillende factoren helpt om de gelijksoortige en verschillende patronen van het productontwikkelingsproces nader te verklaren, alsook de drijfveren, timing, en frequentie van de ontwerpexperimenten en stakeholderinteracties. Op basis van deze verschillende patronen, kunnen twee verschillende benaderingen voor de ontwikkeling van product-markt combinaties worden geïdentificeerd: (1) de adaptieve benadering; gekenmerkt door een focus op een specifiek product-markt combinatie in het begin, het daarmee experimenteren gedurende meerdere jaren en het aanpassen op basis van ontwerpexperimenten en stakeholders interacties, en (2) de exaptieve aanpak, gekenmerkt door een flexibele houding ten opzichte van de product-markt combinatie, het instrumentele gebruik van ontwerpexperimenten voor het genereren van nieuwe opties, en een sterke focus op interacties met stakeholders. Terwijl een adaptieve aanpak wordt nagestreefd om met als doel product-markt-ideeën te convergeren, wordt een exaptieve benadering gevolgd voor het verkennen van alternatieve opties en is zodoende divergerend. Ten slotte suggereren de resultaten van deze studie dat duurzaamheidsmotivatie de betrokkenheid van ondernemers bij een bepaalde product-markt-combinatie doet toenemen tenzij de rechtvaardiging van duurzaamheidsvoordelen in alternatieve marktsegmenten, in de perceptie van de ondernemers, relatief eenvoudig is. Ter afsluiting geeft hoofdstuk 8 een aantal aanbevelingen gericht op product innovatie- en ondernemerschaps-theorieën, in het bijzonder gericht op het verder testen van het conceptuele model en het herformuleren van de proposities.

De bevindingen van dit onderzoek dragen bij aan een beter begrip van het productinnovatieproces in nieuwe ondernemingen. De studie voorziet ondernemers, vooral beginners, design professionals en studenten die overwegen om een nieuwe onderneming op basis van een duurzaam idee product te starten relevante nieuwe inzichten. In het bijzonder betreft dit het begrijpen van de verschillende type besluitvorming logica's en hun gevolgen voor het productontwikkelingsproces. Inzicht in dit proces kan bedrijven ondersteunen bij het simultaan en door elkaar heen gebruiken van verschillende benaderingen tijdens het innovatieproces, onder verschillende omstandigheden van onzekerheid. Dit stelt hen in staat om effectiever geëngageerd te raken bij de ontwerpexperimenten en interacties met stakeholders met verschillende doeleinden. Ten slotte beveelt deze studie nieuwe ondernemingen aan om ook in het geval van een sterke duurzaamheidsambitie en –idealen, de bedrijfs- en nieuwe productontwikkeling te combineren met betaalbare kleine stappen om ruimte te creëren voor experimenten en zo de leereffecten in relatie tot duurzaamheid te verhogen om daarmee ook duurzaamheid een realistische basis in bedrijf en producten te kunnen geven.

Summary in Turkish

Özet

İnovasyonun gezegenin ve gelecek kuşakların sürdürülebilirliği için gerekli değişimi sağlamakta oynadığı rol, teori ve pratikte yaygın olarak kabul edilmektedir. Sürdürülebilir inovasyonlar, organizasyonların çevresel etkiyi düşürüp sosyal refahı artırırken toplumdaki mevcut pratikleri dönüştüren yeni ürün, hizmet ve pazarlar tasarlaması ve geliştirmesini gerektirmektedir. Sürdürülebilirlik ve iş dünyası bağlamında, yeni firmalar giderek daha çok sürdürülebilirlik için gerekli inovasyonu yaratacak adaylar olarak kabul edilmektedir. Sürdürülebilirlik, doğası gereği geleceğe yapılan belirsiz bir yolculuktur ve girişimci eylem, belirsizlik güdümlüdür. Bu kabule karşın, yeni girişimlerin bu süreçte belirsizlikle nasıl başa çıktıkları hakkında çok az bilgiye sahibiz. Girişimcilik bağlamı, yeni ürün geliştirme ve sürdürülebilirlikle ilişkili olarak karar vermeyi nasıl etkiler? Sürdürülebilirlik motivasyonunun inovasyon sürecine etkileri nelerdir? Ürün inovasyonu sürecinin girişimcilik bağlamında sürdürülebilirlikle ilgili olarak nasıl meydana geldiği bu çalışmanın ana sorusunu oluşturmaktadır.

Yeni girişimler şüphesiz büyük ölçekli organizasyonların minyatürleri değildir. Farklı örgütlenme düzeni ve karar verme süreçlerine sahiplerdir. Bir yandan, endüstriyel koşulların dinamiklerine daha çabuk cevap verebilmelerini sağlayan esnek karar verme süreçleri sebebiyle inovasyonda daha avantajlı görülürler. Diğer yandan ise, yeni ve küçük ölçekli olmaları nedeniyle yüksek düzeyde belirsizlikle karşı karşıyalardır. Yeni girişimler genellikle, inovasyonları pazara sürmek için gerekli olan kaynak ve becerilere sahip değildir. Dahası, sürdürülebilir inovasyon özelinde, yeni ürünlerin sürdürülebilirlik faydalarını müşterilere ve paydaşlara gösterme ve ispatlama zorluğuyla karşılaşırlar. Bu zorluklar hesaba katılınca, yeni girişimler, ürün inovasyon süreci başlangıcında umut vaat eden ürün-pazar kombinasyonlarını genellikle belirleyemezler ve bunun yerine sürekli olarak iş fikirlerini kademeli olarak yeniden tanımlarlar. Bu keşif çalışmasının amacı, bu sürece dair derinlikli bir anlayış kazanmaktır: (1) Yeni girişimlerdeki ürün geliştirme nasıl betimlenebilir? (2) Yeni girişimlerin benzerlik ve farklılıklarını açıklayan nedir? (3) Girişimcilerin sürdürülebilirlik motivasyonu ürün inovasyon sürecini nasıl etkiler?

Bu tezdeki 2. Bölüm, ürün inovasyonu literatürünü, ürün inovasyon süreçlerinin nasıl betimlenebileceğini anlamak amacıyla incelemektedir. Literatürdeki inovasyonların yenilikçilik derecelerini temel alarak, bu çalışmanın odağı, mevcut pratiklere meydan okuyan yeni ve radikal ürün geliştirme olarak belirlenmiştir. Radikal inovasyonlar, müşteriye ve inovasyon sürecini yöneten firmalara yeni oluşları sebebiyle, artımsal inovasyona kıyasla doğası gereği daha belirsizlerdir. Bu yüzden, bir firmanın radikal yeni ürün geliştirme yeterliği, sadece teknolojik değil, aynı zamanda pazarlama becerisi, bilgisi ve kabiliyeti gerektirir. Dahası, yeni girişimler özelinde belirsizlikler aynı zamanda, pahalı ürün geliştirme sürecine girmek için gerekli kaynak ve kabiliyet eksikliğinden kaynaklanır. Bu zorluklar düşünülerek, yeni girişimlerdeki ürün inovasyon süreci, belirsizlik azaltmaya yönelik bir dizi tasarım deneyine dayanan döngüsel bir öğrenme süreci olarak kavramsallaştırılır. Tasarım deneyleri ile firmalar, belirli ürün-pazar fikirlerinin sınır ve imkanlarını kademeli olarak öğrenirler. Tasarım deneyleri, firmaların ürün-pazar ikilisini öğrendikleri bilgiye dayanarak kademeli olarak tanımlamalarını sağlar.

3. Bölüm'de, fırsat belirleme ve karar verme üzerine girişimcilik literatürü incelenmektedir. Nedensel-etkisel ('causal-effectual') yaklaşımların karşıtlığı, yeni girişimlerin ürün inovasyon süreçlerindeki benzerlik ve farklılıklarını açıklamak için yorumlayıcı bir lens olarak seçilmiştir. Bu karşıtlık, rasyonel karar verme teorilerini, zaman içinde beliren ve organik bir süreç tanımlayan güncel teorik perspektiflerle birleştirir. Ürün inovasyon sürecini etkilemesi muhtemel olan girişimcilik birikimi, firmaların kaynak pozisyonu ve girişimcinin algıladığı belirsizlik gibi çeşitli etmenler belirlenmiştir. Devamında, 4. Bölüm, sürdürülebilir girişimcilerin motivasyonunun, onları ticari girişimcilerden farklılaştıran en önemli etmen olarak belirlendiği, yeni ortaya çıkan sürdürülebilir girişimcilik alanını incelemektedir. Bu çalışma, sürdürülebilirlik odaklı yeni girişimlerin ürün inovasyon süreçlerdeki benzerlik ve farklılıklarını açıklamak için bu etmenlerin tek ve birleşik etkilerini önermektedir.

Yeni girişimlerin sürdürülebilir ürün fikirlerini yeni iş modellerine nasıl dönüştürdüklerini tam olarak anlamak için, literatürde belirlenen anahtar kavramların ilişkilerini dikkate alarak, süreç odaklı bir araştırma yaklaşımı benimsenmiştir. 5. Bölüm'de, literatürde belirlenen anahtar kavramlar kullanılarak, sürdürülebilirlik motivasyonu olan yeni girişimlerdeki ürün inovasyon sürecini betimleyici bir model geliştirilmiştir. Bu model, ürün-pazar ikilisinin iki belirgin eylemden şekillendiğini önermektedir: tasarım deneyleri ve paydaş etkileşimleri. Buna bağlı olarak, inovasyon süreci üç değişkeni temek alarak kavramsallaştırılmıştır: (1) ürün-pazar amaçları, (2) tasarım deneyleri ve (3) paydaş etkileşimleri. Buna ek olarak, yeni girişimlerin inovasyon süreçleri bu üç değişkene bağlı olarak benzerlikler ve farklılıklar göstermektedir. Buna uygun olarak, yeni girişimlerin inovasyon süreçlerindeki benzerlik ve farklılıkları açıklamak için betimleyici modelin bu üç değişkenini ve literatürde belirlenen etmenleri temel alan kavramsal bir model önerilmiştir. Sonuç olarak, bu etmenlerin, ürün-pazar kombinasyonlarına dair kararlar ve girişimcilerin eylem tipleri (yani, tasarım deneyleri ve paydaş etkileşimleri) üzerindeki etkilerini öngören savlar sunulmuştur. Sürdürülebilirlik odaklı dört yeni girişim vakası şu amaçlarla seçilmiştir: (1) benzerlikleri açıklamak için harfi çoğaltma ve (2) zıt sonuçları öngörmek için teorik çoğaltma. Veriler, hem röportajlardan, hem de vaka firmalardan ve internet makalelerinden sağlanan tamamlayıcı dokümanlardan toplanmıştır. Dört vakadan üçü, 2009 ve 2013 yılları arasında izlenmiş ve röportajlar yapılmıştır. Daha sonra, önceki vakalarla yeterli zıtlığı oluşturacak ek bir vaka daha seçilmiş ve 2012 ve 2013 yılları arasında izlenmiştir. Bu çalışma, vaka betimlemeleri ve teorik savları, vaka çalışması araştırması ve analizinde yol gösteren iki ana veri analiz stratejisi olarak kullanmaktadır.

6. Bölüm, vaka firmaların ürün inovasyon süreçlerinin tarihsel hikayelerini önerilen betimleyici modeli temel alarak sunmaktadır. Bu vaka hikayeleri, her firmanın meşgul olduğu tasarım deneyleri ve paydaş etkileşimlerinin ve de bunların neticelerinin arkasındaki gerekçeyi açıklamaktadır. Vaka çalışması, firmaların tasarım deneyleri ve paydaş etkileşimlerini çeşitli sebeplerden yaptığını göstermektedir; bunlar: teknik fizibiliteyi ve belirli bir ürün-pazar kombinasyonunun pazar elverişliliğini test etmek, tanıtım, paydaşların ilgisini kazanma ve gelir elde etmektir. Ayrıca, ürün-pazar tanımlarının gelişimi, tasarım deneyleri ve paydaş etkileşimlerinin tip, sıra ve zamanlaması, çeşitli kalıplar ortaya koymaktadır. Vaka

firmaları, çeşitli ürün-pazar fikirleri, tasarım deneyleri ve paydaş etkileşimleri ile neden ve nasıl meşgul olduklarını açıklamak için analiz edilmiştir.

7. Bölümde, vakaların kavramsal modelde önerilen etmenlere ve 5. Bölümdeki savlarda öngörülen kalıplara göre analiz edildiği ve karşılaştırıldığı çapraz vaka analizi sunulmaktadır. Bu etmenlerin, ürün inovasyon süreçlerinin benzerlik ve farklılıklarını açıklamadaki rolü tartışılmaktadır. Teknik belirsizliğin düzeyinin, ürün-pazar ikilisinin tanımını güdümleyen eylem tipini etkilediği gözlenmektedir. Muhtemelen, girişimcilik birikiminin düzeyi ve kaynakların mevcudiyeti firmaların meşgul olduğu ürün-pazar denemelerinin yoğunluk ve sürelerini belirlemektedir. Tasarım deneyi ve paydaş etkileşimlerinin neticelerinin girişimcilerin belirsizlik algısını ve sonuç olarak ürün-pazar geliştirmeye yaklaşımlarını etkilediği gözlenmektedir. Sürdürülebilirlik motivasyonu da muhtemelen ürün-pazar denemelerinin süresini etkilemektedir. Son olarak, vaka firmaların ürün inovasyon süreçleri, ürün-pazar denemelerinin kalıplarını belirlemek amacıyla analiz edilmiştir. Analiz, vaka firmaların ürün-pazar ikilisi tanımlarındaki odak ve esneklik temelinde ve dolayısıyla meşgul oldukları ürün-pazar denemelerinin sayı ve süresi bakımından farklılaştığını göstermektedir. Ayrıca analiz, odaklı ürün-pazar geliştirme dönemlerinin esnek geliştirme dönemleriyle birbirini izlediğini ortaya çıkarmaktadır. Dahası bu bölüm, 5. Bölüm'de sunulan savları vaka çalışması bulgularına dayanarak test etmektedir.

8. Bölüm sonuçları ve önerileri sunmaktadır. Araştırmanın ana bulguları şunları içermektedir: (1) yeni girişimlerdeki ürün inovasyon süreçlerini tanımlayan betimleyici bir model, (2) yeni girişimlerin ürün inovasyon süreçleri arasındaki benzerlik ve farkları açıklayan bir kavramsal model ve (3) sürdürülebilirlik motivasyonunun girişimcilerin ürün inovasyon süreçlerini nasıl etkilediğine dair kavrayış. Betimleyici model, ürün inovasyon süreci boyunca firmaların meşgul olduğu ürün-pazar denemelerini ve de tasarım deneyleri ile paydaş etkileşimlerini yeniden yapılandırıp tarif etmek için faydalıdır. Kavramsal model, çeşitli etmenlerin tek ve birleşik etkilerinin ürün inovasyon sürecinin benzer ve farklı kalıplarını açıklamaya yardımcı olduğunu önermektedir. Bu farklı kalıpların temelinde iki belirgin ürün-pazar geliştirme yaklaşımı belirlenmiştir: (1) adaptif ('adaptive') yaklaşım, başlangıçta belirli bir ürün-pazar ikilisine odaklanma, bununla birkaç yıl boyunca deneyler yapma ve ikiliyi tasarım deneyleri ve paydaş etkileşimlerine dayanarak uyumlu hale getirme ile karakterize edilir, (2) eksaptif ('exaptive') yaklaşım, ürün-pazar ikilisine karşı esnek bir tutum, yeni seçeneklerin oluşturulmasında tasarım deneylerinin enstrümantal olarak kullanımı ve paydaş etkileşimlerine güçlü bir odaklanma ile karakterize edilir. Adaptif yaklaşım ürün-pazar fikirlerinin birleşmesi ('convergent') amacıyla izlenirken, eksaptif yaklaşım alternatif seçeneklerin keşfedilmesi için izlenir ve dolayısıyla ayrıştırıcıdır ('divergent'). Ek olarak, bu çalışmanın bulguları, sürdürülebilirlik faydalarının diğer pazar dilimleri için de doğrulanması - en azından girişimcilerin zihninde - kolay olmadıkça, sürdürülebilirlik motivasyonunun girişimcilerin belirli bir ürün-pazar ikilisine bağlılığını muhtemelen yükselttiğini önermektedir. Son olarak 8. Bölüm, ürün inovasyonu ve girişimcilik teorisini hedefleyen, özellikle kavramsal modelin ve yeniden düzenlenmiş savların sınanmasına yönelik bir dizi öneri sunmaktadır.

Bu araştırmanın bulguları, yeni girişimlerin ürün inovasyon süreçlerine dair daha iyi bir anlayışın geliştirilmesine katkıda bulunmaktadır. Bu çalışma, sürdürülebilir bir ürün fikrine dayanan bir girişim başlatmayı düşünen -özellikle yeni başlayan- girişimcilere, tasarım pratisyenlerine ve öğrencilerine, uygun yeni bir anlayış ve görüş açısı sağlamaktadır. Bu anlayış ve görüş açısı, özellikle ürün geliştirme sürecinde farklı karar verme mantıkları ve bunların uygulamaları ile ilgilidir. Sürece dair tanımlanan bu anlayış, firmaların farklı yaklaşımları eş zamanlı ve dönüşümlü olarak, hem inovasyon süreci boyunca, hem de farklı belirsizlik koşullarında kullanmasında destekleyebilir. Bu, onların tasarım deneyleri ve paydaş etkileşimlerini daha etkili olarak yürütmesine imkan verir. Son olarak bu çalışma, yeni girişimlere, deneyselliğe alan yaratmak ve sürdürülebilirlikle ilgili öğrenme etkilerinin artırmak için, güçlü sürdürülebilirlik vizyonlarını, maliyetleri karşılanabilir küçük adımlarla birleştirmelerini önermektedir.

Chapter 1

Introduction

*In 2005, during the course 'ID5561' on Sustainable Product-Service Systems, industrial design students of Delft University of Technology (TU Delft) developed an innovative solution based on the advances of nanotechnology applied to batteries and founded a firm called Epyon in order to exploit this opportunity. Today, Epyon is considered to be a 'copy-book venture story' from the YES!Delft incubator and is recognized as 'one of the best European cleantech companies of the decade'. When Crijn Bouman, Wouter Smit and Wouter Robers started Epyon, their dream was to create a firm that contributed to the next energy revolution. Hans Streng, who later became the CEO of Epyon, explains their vision by positioning Epyon "as a company that understands best how, where and when to quickly charge batteries with electric energy". Although their innovation worked technically, finding a market was a major challenge; which markets would be interested in fast charging solutions? As Crijn Bouman states, "We were a solution looking for a problem". Epyon initially conducted extensive market research and decided to target the cellphone market. The first product was a one-minute telephone charger called the Flashpack. However, the firm found out the hard way that the consumer electronics market is difficult to access and Flashpack was abandoned before it reached the stores. In the subsequent years, Epyon 'tried out everything' and experimented with a number of product-market combinations such as public fast charging systems, on-board fast chargers, industrial power systems, energy storage systems and solar power systems. The firm eventually decided to keep their focus on fast charging solutions for electric vehicles and succeeded to raise funding from a venture capital firm in 2008. With the venture capital money, they aimed to realize demonstration projects and consequently partner with leading battery companies. The firm installed the first European fast charging station in early 2010 in the Netherlands. When the electric vehicle market began to scale up in early 2011, Epyon was confronted with an increasing amount of orders and consequently, issues of delivery times, payment terms and a growing need for capital. However, as Crijn explains, "We started talks about an order of 300 fast-chargers with ABB, who wanted to sell it under their own brand. In that period, we were also in need of more investment, we first looked towards investors. But then we asked ourselves the question: 'Why don't we ask ABB to buy us?'" In 2011, the firm was acquired by ABB, a world leading power and automation group. Today, the Epyon portfolio is part of ABB's Discrete Automation and Motion division, and includes a range of electric vehicle solutions for all charging standards, remote and connectivity services for network providers as well as a variety of installation, training and maintenance services.**

This kind of success stories regarding sustainability-oriented new ventures is a source of inspiration for practitioners and academics across various disciplines. New ventures are increasingly recognized for delivering new products and services that can address the challenges associated with sustainability. This study attempts to uncover how this process in new firm settings unfolds. For instance, how did Epyon experiment with different products and markets? How did the outcome of these experiments influence subsequent decisions? How and why did Epyon decide to focus on the electric vehicle market? What kind of interactions occurred between Epyon and ABB? How did these interactions influence subsequent decisions?

** The story of Epyon is compiled based on several published articles from the internet.*

With this background in mind, this introduction chapter begins to explain the motivation for studying new ventures and their product innovation process (1.1). Subsequently, a brief introduction to sustainability-oriented new ventures and their particular challenges is given (1.2), and finally, the literature gap (1.3) and research objectives of the study are presented (1.4).

1.1. MOTIVATION

Environmental degradation and social injustice associated with rising global population and increasing resource use are challenges that contemporary society faces today. Within this context, the role of innovation in bringing the necessary change for the sustainability of the planet and future generations is widely acknowledged. Sustainable innovations require organizations to create new products and markets that transform the current practices in society, while decreasing environmental impact and increasing social welfare.

Much of the research at the intersection of business and sustainability has primarily focused on established firms and how they can 'do well by doing good' (e.g. corporate social responsibility, corporate sustainability) and 'do more with less' (e.g. cleaner production, green management, eco-design). For instance, the corporate social responsibility (CSR) research focused on the ethical motivations of corporate managers as the main incentive for engaging with sustainable business practices. The concept of CSR highlights the responsibility of businesses in solving environmental and social issues linked to their operations (Wood, 1991). Although the CSR concept has received much attention in academia and business practice, it is criticized for being a reactive strategy as an attempt to satisfy public reaction (Aguilera, Rupp, Williams, & Ganapathi, 2007). In that sense, engaging in 'triple bottom line' thinking has been proposed as a win-win approach and a more proactive strategy for organizations in achieving economical profitability, as well as environmental and social sustainability. This win-win paradigm has led to a number of concepts such as cleaner production, design for environment, eco-design, and more recently, sustainable innovation in the form of new products and services. The underlying driver behind these concepts is the eco-efficiency thinking; defined as "the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with the earth's estimated carrying capacity" (WBCSD, 1992). In this case, the motivation for organizations to engage in sustainable practices is not only an ethical concern, but also cost reductions and increased revenues through product differentiation and better access to markets (Ambec & Lanoie, 2008).

Despite the accumulation of literature, the focus on corporate 'greening' and the strong influence of eco-efficiency thinking has resulted in an orientation towards incremental innovation through the improvement of production processes, "as opposed to product innovation, where the environmental value is embodied in the commercial output of the firm" (Hellström, 2007). Furthermore, the majority of studies are based on research on large established firms (Larson, 2000). Although large firms are important and have certain advantages for innovation, such as economies of scale and slack resources, some scholars are skeptical whether established firms are doing well in delivering more sustainable products and services (Hall, Daneke, & Lenox, 2010). According to York and Venkataraman (2010), there are a number of barriers for established firms to engage with environmental innovation. First of all, the trade-offs and the challenge of economically justifying environmental innovations might hinder established firms in engaging with more sustainable practices. Often, the issues related to sustainability are not well understood: Do they exist? How severe are they? How can they be best addressed? These inherent uncertainties linked to sustainability require 'action in the face of ambiguity', which established firms are often not well equipped for due to organizational routines and inertia (York & Venkataraman, 2010). Furthermore, established organizations frequently possess market share in existing markets, and as a result they may have few incentives for investing in new products (Ali, 1994), or withdrawing from previous investments in manufacturing processes (Hockerts & Wüstenhagen, 2010; Nicholls, 2006). In that sense, the idiom "you cannot teach an old dog new tricks" resonates well with established firms.

These criticisms and insights have recently brought back the 'innovative entrepreneur' of Joseph Schumpeter into the debate of sustainability and business (Hall et al., 2010; Larson, 2000). According to Schumpeter (1934), entrepreneurs destroy existing structures and create novel ones through a mechanism what he called 'creative destruction'. In this respect, some scholars have been drawing attention to the role of entrepreneurial action in solving issues related to sustainability by destroying existing practices and institutions with novel sustainable products and services that established firms fail to do so (York & Venkataraman, 2010), addressing environmentally relevant market failures (Dean & McMullen, 2007), creating the future by ignoring current market demand (Fussler & James, 1996), transforming industries and mass-markets beyond eco-niches (Schaltegger & Wagner, 2011) as well as addressing the unmet needs in low-income markets, i.e. 'bottom of the pyramid' (BoP) market (Prahalad, 2006) and transforming institutional context for the benefit of poor and marginalized groups (Alvord, Brown, & Letts, 2004). New firms are increasingly recognized as the candidates to bring about innovations necessary for sustainability. The rationale behind this recognition is twofold. Firstly, sustainability is inherently an uncertain journey into the future, and "entrepreneurial action is driven by uncertainty rather than stymied by it" (York & Venkataraman, 2010). Secondly, new firms generally have certain advantages for innovation due to being small and new. They posses flexible decision-making processes and lack organizational inertia; which is often a barrier for innovation in case of large firms (Dean, Brown, & Bamford, 1998).

Despite the promise of new ventures to deliver new products and services for sustainability, little is known about how these companies actually engage in this process. Studies on product innovation processes within new entrepreneurial organizations are limited. Comprehensive studies on sustainability-oriented new ventures and their product innovation process are even more scant (for an exception, see Berchicci, 2005). How does the entrepreneurial context influence decision-making in relation to product development and sustainability? How do entrepreneurs develop products in new firm settings? What are the implications of sustainability motivation for the innovation process? How do entrepreneurs deal with the “constant tension between running a viable business and staying true to ideals” (Dixon & Clifford, 2007)?

Understanding how new ventures engage in new product development processes and how the entrepreneurs’ motivation influences this process is crucial for the development of novel sustainable products, as well as the success and survival of new ventures. Accordingly, this study revolves around product innovation processes in new ventures; driven by an issue related to sustainability. The focus is given to new products that significantly depart from existing products, i.e. products that are new to the customers and to the firms that are engaged in this development process. Furthermore, the interest of this study is new ventures that pursue social and/or environmental goals in addition to financial goals.

1.2. SUSTAINABILITY-ORIENTED NEW VENTURES

Despite arguments that new firms are better at innovation, they face challenges in commercializing innovations because of liabilities of being new and small. On the one hand, due to a lack of brand recognition, new firms face the challenge of product differentiation and market acceptance, which increases the market uncertainty and the need for financial resources such as advertising (Aldrich & Auster, 1986). On the other hand, developing a product may entail higher costs for new firms due to the lack of scale and an established production system (Aldrich & Auster, 1986). This, in turn, increases the technological uncertainty and the need for capital. Besides these additional costs, new firms do not often possess all the resources necessary for innovation development (Maillat, 1990). In order to overcome these shortcomings, they exploit networks to acquire a variety of resources possessed by other actors; however, they face other barriers in this acquisition process. As opposed to established firms, new firms lack legitimacy; which might negatively influence market transactions and interactions with stakeholders (Aldrich & Fiol, 1994). Furthermore, entrepreneurs are confronted with higher levels of uncertainty during the decision-making process, in comparison to managers in large organizations (Busenitz & Barney, 1997). Entrepreneurs often have to make their decisions in the absence of historical trends, past performance data and specific market information; all of which large organizations have access to and can benefit from reducing the level of uncertainty. For this reason, new firms are confronted with high levels of uncertainty concerning the market acceptance of new products and services (Busenitz & Barney, 1997).

In addition to the uncertainties associated with entrepreneurial settings, new ventures motivated by an issue related to sustainability face decisions concerning 'what products to develop for which markets', and 'with what social and environmental consequences'. Innovations for sustainability entail additional uncertainties stemming from their long-term impacts, as well as the additional environmental and/or social dimensions. Sustainable innovations require firms to "consider issues outside their area of expertise, far beyond the boundaries of the individual firm and over time periods much, much longer then the typical product-planning horizon" (Thurston, 1999). Moreover, there is a lack of consensus on the meaning and definition of the concept of sustainability (Faber, Jorna, & Van Engelen, 2005). Different people perceive the terms 'social' and 'sustainable' differently. This hinders the progress in research and practice; particularly in relation to entrepreneurial outcomes. The measurement of social and environmental impact is difficult, if not impossible. For instance, Dees and Anderson (2003) state, "Social benefits are often intangible, hard to quantify, difficult to attribute to a specific organization, best evaluated in the future, and open to dispute". In turn, this runs the risk of adverse social consequences (Zahra, Gedajlovic, Neubaum, & Shulman, 2009), creates challenges for making bottom line decisions and demonstrating social benefits (Dees & Anderson, 2003), as well as aligning interests of the various stakeholders (Austin, Stevenson, & Wei-Skillern, 2006). From an environmental impact perspective, others highlight the complexity of greening by arguing that it is an ill-defined concept and perceived differently by customers, producers and government. For this reason, it is suggested that the integration of environmental concerns into business and product development increases the complexity of decision-making process (Baumgärtner, Faber, & Proops, 2002). Additionally, differentiating environmental and social goals might be challenging, as Walley and Taylor (2002) state, "Green and ethical entrepreneurs may well have mixed motivations; their motives may not be solely green but be a combination of green, ethical and social motives, and it is often difficult to separate these (as, indeed, the concept of sustainability reflects)".

Considering these uncertainties and challenges, questions arise regarding how product innovation processes unfold in sustainability-oriented new ventures that are confronted with decisions concerning their social and environmental impact, a lack of market recognition and a weak financial position. What are the implications of these challenges for the product innovation process? How can the product innovation process in new ventures be described? What are the implications of pursuing multiple goals?

1.3. LITERATURE GAP: PRODUCT INNOVATION PROCESS IN NEW VENTURES

In order to understand how sustainability motivation of entrepreneurs influences the product innovation process, there is a need to gain a better understanding of the actual product innovation process in new ventures. Schumpeter's notion of 'innovative entrepreneur' relates to two fields of disciplines. On the one hand, literature on innovation management addresses firm-level decisions concerning the product innovation process and several scholars have proposed models for this process (Chesbrough, 2004; Cooper, Edgett, & Kleinschmidt, 2002). Moreover, innovation studies are concerned with identifying different types of innovation and their implications for innovation process; hence they provide insights into how firms manage innovation. On the other hand, the discipline of entrepreneurship has been occupied with how individual entrepreneurs identify an opportunity and acquire the necessary resources in exploiting it. In this regard, literature on entrepreneurship offers various theoretical perspectives in explaining how the entrepreneurial process unfolds, and how the similarities and differences in entrepreneurial behavior can be explained.

Innovation management research

Innovation management literature offers two perspectives on how the innovation process might unfold on the basis of varying degrees of innovativeness (i.e. incremental versus radical innovation): the rational and the non-rational view of the innovation process (e.g. Berchicci, 2005; Hellman, 2007). The rational view of the innovation process has emerged from decades of research on new product development (NPD) processes in large established firms. This stream of the literature has proposed several process models and identified formalized product development processes and well-planned activities as best practices, which are demonstrated to be effective in large established firms. The stage-gate model of Cooper et al. (2002) and more recently the open innovation model of Chesbrough (2004) portray good examples of such models that describe an analysis-driven linear process. A common feature of these models and frameworks is that innovation is conceptualized as a rational problem solving process. The underlying assumption behind the rational view is that the problem, such as a customer need, is known at the outset of the innovation process and a solution can be identified through a goal-oriented step-wise process. The process is initiated by the definition of a goal, or identification of an opportunity through various information-gathering methods, such as market research, technology forecasting and scenario planning. Therefore, an essential responsibility of the innovation team is to make sure that all relevant information is acquired in the early phases of the innovation process. Accordingly, alternative solutions are generated and rationally evaluated in order to choose the most promising solution for development. In this way, uncertainty can be reduced to a manageable degree for decision-makers. Due to the focus on forecasting and prediction, these approaches are referred to as ‘planning approaches’ (Wiltbank, Dew, Read, & Sarasvathy, 2006). Although these rational models are effective in large firms and useful for research and educational purposes, Buijs (2003) argues that the innovation process in practice has a more chaotic character. Furthermore, empirical research suggests that small firms do not often use such formalized practices. In this regard, some scholars have questioned whether this is a shortcoming of small firms; which can be fixed by the adoption of such structured approaches, or that small firms require other management practices due their distinct characteristics (Berends et al., 2014). It has also been questioned how product innovation might unfold when there is a lack of information about future technological and market space (e.g. Hürzeler, 2013; Silberzahn, 2011), as well as the exact sustainability benefits of an innovation (Paech, 2007).

In contrast to the rational view, radical innovation scholars conceptualize innovation as a non-rational process due to the inherent uncertainties linked to radical innovations. The central idea behind the non-rational view is that the innovation process may not start from a well-defined opportunity and entails “unexpected twists and turns” (Schön, 1967, p. 12). This is particularly true in the case of new firms and as Drucker aptly puts it: “When a new venture does succeed, more often than not it is in a market other than the one it was originally intended to serve, with products and services not quite those with which it had set out, bought in large part by customers it did not even think of when it started, and used for a host of purposes besides the ones for which the products were first designed” (Drucker, 1985, p. 189). As a result, planning becomes an irrelevant activity due to the impossibility of predicting the emergence of future states (Burns & Stalker, 1961). There is limited information to rationally evaluate the alternatives and predict outcomes (Hellman, 2007). According to the non-rational view, the innovation process is illustrated as an iterative process; in which learning from experiments is a fundamental problem-solving activity. The information generated through experiments helps firms to reduce uncertainty and act quickly in order to capture emerging opportunities (Wiltbank et al., 2006). These ‘learning approaches’ emphasize flexibility and adaptation over prediction (Wiltbank et al., 2006). The innovation process is portrayed as an iterative learning process.

Considering the high levels of uncertainty sustainability-oriented new ventures are confronted with, the non-rational view of the innovation process appears to be a more suitable framework in describing and analyzing the product innovation process in new ventures. Indeed, empirical evidence suggests that small firms’ approach resembles radical innovation approaches; even when they are engaged with incremental innovations (Berends et al., 2014). Therefore, it is expected that defining a product-market (PM) combination at the outset of the innovation process will be difficult. Entrepreneurs learn about the technical and market feasibility of their ideas through a number of experiments, and based on the outcome of these experiments they progressively define their business idea over time; however, it is likely that this iterative experimental process will vary among new ventures. In explaining the similarities and differences of this process, entrepreneurial decision-making theories are consulted.

Entrepreneurship research

The discipline of entrepreneurship broadly offers two theoretical perspectives on the decision-making process of entrepreneurs. On the one hand are the traditional theories, which draw largely on ‘planning approaches’ in order to describe how entrepreneurs discover opportunities and acquire resources to exploit a pre-defined opportunity at the outset of the process. The underlying assumption of the traditional theories is that opportunities exist independent from entrepreneurs, and the task of the entrepreneur is to simply be alert in discovering opportunities. New firms are created through a linear process of “opportunity identification, evaluation and exploitation of these opportunities” (Shane & Venkataraman, 2000). In this process, opportunities are evaluated based upon systematic information gathering and expected financial returns. The existence of a market for a product or a service and the availability of historic information are necessary conditions for traditional approaches to be applicable (Sarasvathy, 2008).

On the other hand are the emerging theoretical perspectives, which assume that opportunities do not wait out there to be perceived and discovered by individuals, but are created through the actions of entrepreneurs, hence they are socially constructed (Alvarez & Barney, 2007). Particularly, in situations of uncertainty, entrepreneurs emphasize 'control' over prediction and action over information gathering (Sarasvathy, 2008). As opposed to the 'planning' and 'learning' approaches, which assume that the environment organizations operate in is beyond their control; the control-based 'transformative approaches' assume that organizations can shape their environment (Wiltbank et al., 2006). The logic of effectuation introduced by Sarasvathy (2001a) portrays an example of control-based approach. In an effectual process, a set of available means is transformed into an opportunity by a series of stakeholder commitments. This implies focusing on available resources at hand when evaluating an opportunity as it emerges. This process is driven by stakeholders who are willing to commit to the emerging venture (Sarasvathy, 2001a). Sarasvathy (2001a) labels the traditional approaches as 'causation', and emerging control-based approaches as 'effectuation'. The underlying assumption is that entrepreneurs are likely to use causal and effectual logics at varying degrees based upon their level of entrepreneurial expertise, and the level of uncertainty they are confronted with. As such, entrepreneurial processes seemingly vary based upon the logic adapted by entrepreneurs. In this regard, the causation-effectuation dichotomy appears to be a suitable lens in explaining similarities and differences among new ventures' product innovation over time; particularly how they engage in experimentation and progressively define their PM combinations.

The first attempts that explore the implications of effectuation for product innovation in small and medium sized enterprises (SMEs) and technology-based new ventures have been conducted by Berends et al. (2014) and Reymen et al. (2015), respectively. Recent studies have also begun to address the behavioral implications of causation-effectuation for new venture creation. There is however, limited research on the dynamics of causation and effectuation for the product innovation process in new ventures. Studies that examine the implication of these distinctive decision-making logics for sustainable entrepreneurship are even more scant. Considering this gap in literature, this study will focus on: (1) the product-market iterations and the actions taken by entrepreneurs in their attempt to identifying a promising opportunity (i.e. product-market combination), (2) the patterns of product innovation process, and (3) the influence of sustainability motivation on this process.

1.4. RESEARCH OBJECTIVE AND QUESTIONS

Due to the practical relevance of the subject and the lack of theoretical insights as illustrated above, this study attempts to contribute to the understanding of how the product innovation process unfolds in sustainability-oriented new ventures. The first objective of this study is to conceptually integrate the theoretical perspective in the fields of innovation management and entrepreneurship, in order to *describe* and *explain* the product innovation process in new ventures. In particular, this study aims to understand the actions and factors that drive the evolution of PM definitions. Accordingly, patterns of product innovation processes can be derived and the similarities and differences among new ventures' product innovation can be explained. The second objective of this study is to enrich the research on sustainable entrepreneurship by providing an understanding of how sustainability motivation influences PM decisions, the actions taken by entrepreneurs and how the entrepreneurial process influences the motivation of entrepreneurs over time. Therefore, the central research question of this study is:

How does the product innovation process evolve
in sustainability-oriented new ventures?

To answer the central question, the following three main research questions are posed:

Describing the product innovation process

1. How can the product innovation process in new ventures be described?
    - 1a. How do new ventures manage the product innovation process?
    - 1b. What actions drive the innovation process in new ventures, in particular the definition of product-market combinations?

Explaining the product innovation process

2. What explains the differences and similarities among new ventures' product innovation processes, in particular the evolution of product-market definitions?
    - 2a. What factors influence the product innovation process in new ventures?
    - 2b. What patterns of product innovation processes can be identified?
    - 2c. What explains the similarities and differences in patterns of product innovation processes?

Influence of sustainability motivation

3. How does the sustainability motivation of entrepreneurs influence the product innovation process?
    - 3a. How does sustainability motivation vary among entrepreneurs?
    - 3b. How does sustainability motivation influence the decision-making process, in particular the definition of product-market combinations?
    - 3c. How does sustainability motivation evolve over time?

In answering these research questions, two lines of inquiry are pursued: theoretical and empirical. Table 1.1 presents an overview of how each research question is addressed through theory and empirical findings of this research.

Table 1.1. Overview of research questions and chapters

	Theoretical part				**Empirical part**	
	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7
RQ 1a						
RQ 1b						
RQ 2a						
RQ 2b						
RQ 2c						
RQ 3a						
RQ 3b						
RQ 3c						

Firstly, a theoretical inquiry is conducted in order to understand how product innovation can be described in new ventures, and to identify the actions that drive this process. For this purpose, Chapter 2 reviews the innovation management literature in addressing RQ 1a and 1b. This chapter provides an overview of innovation typologies and their implications for the product innovation process. Additionally, literature is reviewed in order to understand the implications of entrepreneurial context on the innovation process. Iterative experimental approaches are selected as a useful lens to examine the product innovation process in new ventures.

Subsequently, Chapter 3 reviews the entrepreneurship literature with an emphasis on decision-making theories and their implications for the product innovation process. This chapter provides an overview of key factors that are likely to influence the evolution of product innovation process (RQ 2a). Additionally, this chapter explores what actions might drive the product innovation process in entrepreneurial settings (RQ 1b).

Although the research on the motivation of entrepreneurs and how these motivations translate into particular actions is limited, Chapter 4 reviews the literature on sustainable entrepreneurship with a focus on definitions of sustainable entrepreneurship. This chapter also examines a handful of conceptual and empirical studies that focus on the entrepreneurs' motivation in solving issues related to sustainability and how motivations vary among entrepreneurs (RQ 3a and 3b).

The key concepts identified in Chapter 2, 3 and 4 are brought together in Chapter 5. A descriptive model considered to be useful in describing the innovation process of new ventures (RQ1) is proposed. In addition, a conceptual model is presented in order explain the evolution of product innovation process in new ventures. This conceptual model is useful in explaining the similarities and differences among innovation processes and predicting patterns of product innovation process (RQ 2a).

Following the theoretical inquiry, an empirical inquiry is conducted through a case study research. The case study approach is an appropriate research strategy in understanding how new firms translate sustainable products into new businesses and the relationship between key concepts over time. The models proposed in Chapter 5 are used to guide the data collection and analysis. The details of the research approach are presented in section 5.5. The case study research aims to gain an in-depth understanding of new ventures' decisions concerning PM combination, and what explains the shifts and continuation of particular product concepts and target markets. Chapter 6 presents a detailed account of the case firms' product innovation process and a within-case analysis of the firms' actions and PM decisions over time (RQ 1b and 2a). Additionally, the evolution of entrepreneurs' sustainability motivation is discussed (RQ 3c).

Chapter 7 presents a cross-case analysis of the similarities and differences in patterns of product innovation process among case firms and the factors influencing this process (RQ 2b and 2c). In the cross-case analysis, theoretical propositions (5.4) are used to match the predicted and empirical patterns, in order to validate the descriptive and conceptual model. Furthermore, an analysis of how entrepreneurs' motivation influences the innovation process is discussed (RQ 3b and 3c).

In Chapter 8, the main research findings that address the research questions are discussed and conclusions are drawn. Finally, contributions to the innovation management and entrepreneurship literatures are discussed, and recommendations for practitioners and academics are proposed.

Thesis outline

The outline of this study is illustrated in Figure 1.1. Chapter 2 presents various models of product innovation process and identifies the most important theoretical constructs. In Chapter 3, various entrepreneurial decision making approaches are reviewed to further specify the literature gap. Chapter 4 reviews the sustainable entrepreneurship literature with a focus on how sustainability motivation of entrepreneurs influences the decision-making process of entrepreneurs. The findings derived from these chapters are synthesized into a conceptual framework in Chapter 5. This framework is then used for data collection and analysis as a sensitizing lens. In Chapter 6, the case study is described in terms of innovation trajectories. Chapter 7 presents an analysis of the case study. The final chapter provides the conclusions and recommendations.

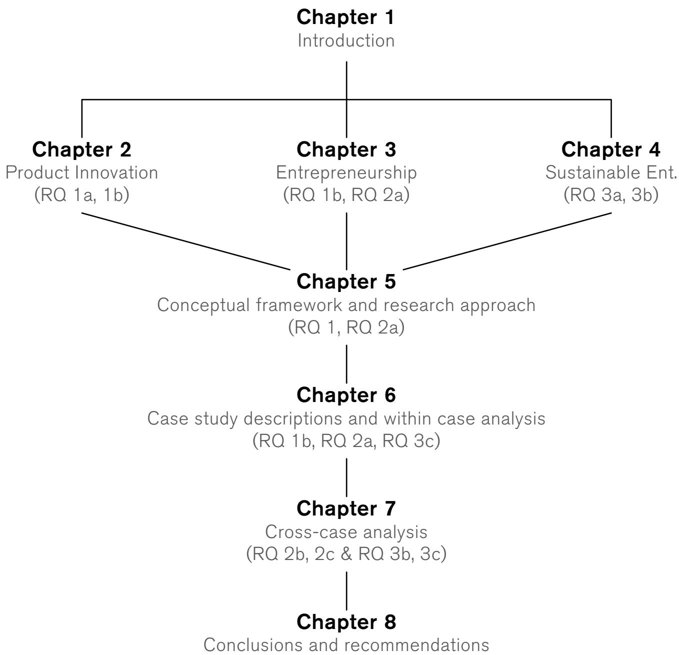


Figure 1.1. Outline of the study

Chapter 2

Product Innovation

The discussion in Chapter 1 has shown that sustainability-oriented ventures are confronted with high levels of uncertainty due to their distinct organizational characteristics, as well as the challenge of evaluating and communicating sustainability benefits of their products. Sustainability-oriented ventures face decisions concerning which products to develop for whom, at which point in time and with what social and environmental consequences. With a focus on these challenges, this chapter reviews the product innovation literature in addressing the following research questions:

- How do new ventures manage the product innovation process? (RQ 1a)
- What actions drive the innovation process in new ventures, in particular the definition of product-market combinations? (RQ 1b)

In order to answer these questions, the literature has been reviewed on the types of innovations and their implications for the product innovation process. This review provides a brief evolution of how innovation has been studied since Schumpeter first coined the term and presents various typologies of innovation (2.1). Since this study revolves around new ventures motivated by an issue related to sustainability, innovativeness from a sustainability perspective is also discussed in section 2.1. Subsequently, implications of the uncertainty that are linked to different types of innovation are examined, different innovation process models are presented and the implications of entrepreneurial context for the innovation process are discussed (2.2). In section 2.3, management practices for reducing uncertainty are presented (2.3). Finally, conclusions are drawn in section 2.4.

2.1. INNOVATION

Innovation is widely acknowledged to play a central role in social and technological change processes, solving issues related to today's modern society and in particular to enabling its sustainability. The term innovation got into the dictionary of many by Schumpeter, who defined innovation as: "The commercial or industrial application of something new – a new product, process or method of production; a new market or source of supply; a new form of commercial, business or financial organization" (Schumpeter, 1934, p. 73). Since then, interpretations of innovation have evolved significantly.

Initial studies conceptualized innovation from an input-output perspective; with a focus on the allocation of resources and the impact of innovation on the economy (Fagerberg, 2004). This macro-view of innovation led to studies on life-cycle theories that explained the birth and emergence of industrial sectors as well as industries based on radical product innovation (Trott, 2008). Although these studies increased the understanding of how innovations differ across industries (Fagerberg, 2004), they failed to explain how innovations actually occur on an organizational level. Even Schumpeter did not focus on the organizational dimension, but advised others to do so (Fagerberg, 2003).

Today, innovation is no longer perceived as an outcome of individual action, but as a learning process: e.g. “a problem-solving activity” (Dosi, 1982), “a process of learning by interacting” (Lundvall, 2009), and “an organizational learning process” (McKee, 1992). A number of disciplines, from economics and management to organizations and design, studied innovation with the aim to explore the black box of the innovation process. As a consequence, the focus of contemporary innovation studies has been shifting from a macro-level to a firm-level; with the focus on process of knowledge generation and its application in new products, as well as the commercial exploitation of these products (Trott, 2008).

New products are perceived to be a crucial source for the firm survival, competitiveness and renewal in new, existing and fast-changing markets (Brown & Eisenhardt, 1995). Furthermore, new products are seen as a means to transform current practices in business and society toward sustainability. In this regard, Schumpeter’s notion of creative destruction has been tempting many scholars; who suggest that innovation can destroy existing processes, industries, markets and systems by making use of the existing and new technologies in innovative ways. From this perspective, the notion of innovation implies that the creation of novel products significantly reduce the environmental impact of existing products and practices, while increasing the well-being of society (Schaltegger & Wagner, 2011). For the purpose of this study, innovation is defined as a commercial activity that generates new products with the potential of challenging existing practices in society towards sustainability. Therefore, the interest here is on product innovation that can potentially address environmental and social challenges of today’s society.

Product innovation process encompasses the process of “transformation of a market opportunity and a set of assumptions about product technology into a product available for sale” (Krishnan & Ulrich, 2001). The events and activities undertaken within this process might vary significantly, depending on the nature of innovation (Van de Ven, Polley, Garud, & Venkataraman, 1999). In this section, variable degrees of innovativeness from a conventional and sustainability perspective are discussed in order to further specify the focus of the study.

2.1.1 Innovativeness in conventional terms

The extant literature on innovation and new product development has extensively attempted to identify the various types of innovation. A number of typologies and terms exist in order to describe the degree of novelty of an innovation such as: ‘architectural’, ‘disruptive’, ‘radical’, ‘really new’, ‘incremental’, ‘sustaining’ and ‘regular’. In distinguishing between different types of innovation, the majority of typologies focus on the degree of technological and market discontinuity that innovations create. Typologies however, vary on the basis of their focus; ‘for whom’ the innovations are new, i.e. firms, industries, marketplace, and customers. Accordingly, literature offers typologies from both a macro and micro-perspective. Macro-perspectives focus on “the capacity of a new innovation to create a paradigm shift in the science and technology and/or market structure in an industry” (Garcia &

Calantone, 2002). Therefore, the degree of newness is evaluated based on the extent to which an innovation is new to the world, industry and market. Micro-perspectives, on the other hand, explore "the capacity of a new innovation to influence the firm's existing marketing resources, technological resources, skills, knowledge, capabilities, or strategy", and in this case, newness is evaluated on the basis of an innovation's degree of familiarity to the customers, as well as the firm engaged in developing it (Garcia & Calantone, 2002).

Although the majority of research adopts a micro perspective and a focus on firm level analysis, a number of typologies exist from a macro perspective. For instance, Abernathy and Clark (1985) emphasize the competitive implications of innovation and distinguish between architectural, niche, regular and revolutionary innovations. Architectural innovations entail new technologies that depart from the established system of production and result in the creation of new industries (e.g. radio) or reformulation of the old ones (e.g. photo typesetting in the printing industry); which subsequently influence the competitive landscape a firm operates in. Niche innovations, on the other hand, strengthen established designs and create new market opportunities through exploitation of existing technologies. An example of niche innovation is Sony's Walkman, which used existing technologies to create a niche in personal audio products. Niche innovations' competitive significance diminishes when they are copied by competitors. Revolutionary innovations, on the other hand, disrupt established technical and production competences for a given market or customers. An example of outmoded established technology is mechanical calculators. Finally, regular innovations build on existing technologies and markets, and have an invisible impact on the competitive landscape; however, their cumulative effect has significant influence on the products' cost and performance. In the same vein, based on his study on technological change, Christensen (1997) distinguishes between sustaining and disruptive innovations, with a focus on the differences between established and entrant firms. While sustaining innovations encompass technologies that increase the performance of existing products in an industry and are introduced by established industry leaders, disruptive innovations involve technologies that create new markets through the introduction of new products by entrant firms of an industry. In product innovation literature, the typology of Kleinschmidt and Cooper (1991) distinguish between high, moderate and low innovativeness. While highly innovative products are new to world, moderately innovative products are new to firm, but not to the market or to the world. Lastly, low innovativeness is defined as modifications or redesign of existing products.

Definitions and typologies from a micro-perspective focuses on firms and their customers and examines a set of factors linked to the degree of newness of technology and market (Garcia & Calantone, 2002). In this regard, Danneels and Kleinschmidt (2001) distinguish two conceptualizations of product innovativeness in literature: 'newness as familiarity' and 'newness as fit'. From a 'newness as familiarity' perspective, newness is defined based on the relationship of an organization to its environment. The product newness is associated with the familiarity of a new product to the established 'domain' of a firm, which is characterized by technological and market environment. Firms are more alert to the information and signals from their established domain (Normann, 1971). Accordingly, Normann (1971) suggests two types of innovations: 1) variations, i.e. new products that are similar to the previous products of an organization, and 2) re-orientations, i.e. new products that are fundamentally different to previous products; with old product dimensions eliminated or new ones added. Re-orientations require a change in the domain of an organization, and encompass greater uncertainty for the organization. On the other hand, 'newness as fit' draws on the resource-based theory of the firm and emphasizes firm resources such as research and development (R&D) expertise, knowledge of customer needs, market research skills and production facilities. As a result, newness of a product is measured based on the fit between the resources a firm controls and the requirements of a new product (Danneels & Kleinschmidt, 2001).

In an attempt to integrate macro and micro perspectives, Garcia and Calantone (2002) propose a triadic categorization that distinguish between radical, really new and incremental innovations. This categorization suggests that innovations differ on the basis 'for whom' the innovation is new (i.e. industry, firm and customer), and the type of discontinuity an innovation creates, i.e. technological versus market discontinuity (Figure 2.1). On a macro level, radical innovations cause market and technological discontinuities, while really new innovations cause either market or technological discontinuities, and incremental innovations cause no discontinuities. On a micro level, radical innovations and really new innovations cause both type of discontinuities, and incremental innovations cause either marketing or technological discontinuity.

Despite the different perspectives on innovativeness, the radical-incremental dichotomy is a common and valid categorization to describe the degree of innovation for both the firm and the outside world, i.e. newness to the firm developing the new product as well as newness to the market (Booz, Allen, & Hamilton, 1982). In this regard, literature on sustainable innovation offers similar typologies with a set of additional qualities and characteristics (Hansen, Bullinger, & Reichwald, 2011).

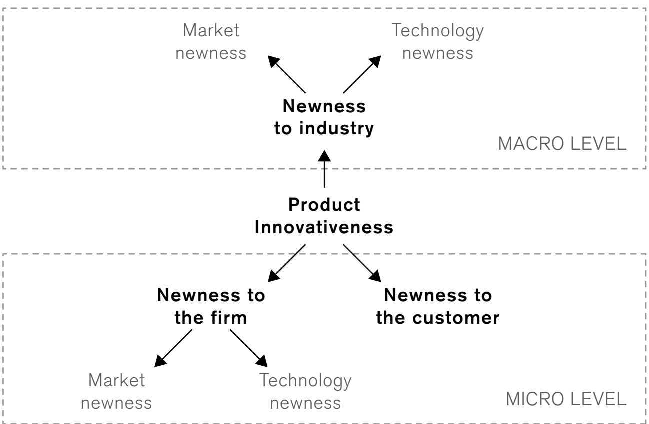


Figure 2.1. Operationalization of innovativeness from a macro and micro perspective (adapted from Garcia & Calantone, 2002)

2.1.2. Innovativeness in sustainability terms

From a historical perspective, the strong influence of eco-efficiency thinking has led eco-innovation research towards incremental innovation with a focus on improving efficiency of the firms' production processes (Hellström, 2007). However, considering the estimations of growing population globally, many scholars call for radical innovations that involve new technologies, as well as innovations that stimulate societal change and consumption reduction; in order to offset the population increase (Charter & Clark, 2007). These developments and criticisms have yielded a number of typologies that distinguish between different types of sustainable innovations.

A growing body of literature focuses on system innovation and transition management and emphasizes innovating beyond the organizational boundaries; in order to influence the broader societal context through changing the social norms, cultural values and institutional structures. For instance, Machiba (2010) distinguishes between incremental and systemic innovations based on the type of technology application, and the potential of an innovation to decouple environmental impact from economic growth (Table 2.1). Systemic innovations have the highest potential in achieving absolute decoupling (Machiba, 2010).

Table 2.1. Application of technologies in different types of innovation (adapted from Machiba, 2010)

Incremental innovation	Systemic innovation
Existing technologies in existing application	Existing technologies in new application
New technologies in existing application	New technologies in new application

Hellström (2007) offers a typology based on technology involved within an innovation (i.e. existing versus new), and whether an innovation represents a new component or a new architecture for a system. According to this typology, incremental/component innovations are those that increase the eco-efficiency of existing processes, e.g. the introduction of new materials and waste minimization. Incremental/architectural innovations aim for system level changes in order to improve eco-efficiency within the boundaries of an existing demand/market, e.g. integrating water reuse into a car wash. Radical/component innovations require the replacement of critical component(s) with new solutions that lower the environmental impact of products/processes, e.g. the introduction of a new technology for heating objects on a production line. Finally, radical/architectural innovations deal with new products and processes that address environmental issues in new ways; resulting in a new architectural structure of an old process, e.g. a new method of water purification with magnetic induction, which replaces the traditional method of chemical purification.

Carrillo-Hermosilla, del Río, and Könnölä (2010) define eco-innovation on the basis of the degree of change an innovation brings about, i.e. whether the changes are competence-enhancing and preserving existing production systems (incremental), or they are competence-destroying and replacing existing systems (radical). They propose three types of eco-innovations: component addition, sub-system change and system change. While component level changes improve the environmental quality of existing systems (e.g. end-of-pipe technologies), system level changes require the redesign of systems and its components that can potentially reduce the environmental impact of ecosystems and society (e.g. eco-effective solutions). Sub-system level changes are eco-efficient solutions that optimize sub-systems by creating products and services that use fewer resources and produce less waste. In a similar vein, Tukker and Butter (2007) distinguish between optimizations, singular innovations and system-level innovations; while Arundel and Kemp (2009) distinguish between sustaining (e.g. catalytic converter, which supports the continued use of the internal combustion engine) and disruptive innovations (e.g. the battery-based electric vehicle). The main message of these authors is the need for radical technological and system change (e.g. the energy system, or the mobility system), which cannot be achieved through incremental innovations.

In the field of design, Brezet (1997) proposes a typology of eco-innovations driven by the 'factor thinking'. Factor thinking implies a reduction of environmental impact of human activity by a factor of 10 to 20 over a period of 30-50 years. Human impact (I) on the environment is calculated by the formula I=P*A*T; where P represents the population; A, the affluence (i.e. average consumption level per capita); and T, the technology (Ehrlich & Holdren, 1972). According to this typology, eco-innovations can be classified into four types: product improvements, product redesign, function innovation and system innovation; with an improvement factor of 2, 5, 10 and 20, respectively. Product improvements entail optimization of existing products from a pollution prevention perspective. Similarly, product redesign involves the improvement of existing product concepts, but requires the replacement of components by non-toxic materials and improvements on the distribution, recycling or energy efficiency; with a focus on the product life cycle. Function innovations focus on the functions and how they are achieved, whether through the development of new products or services. The 'product-service systems' concept is an example of function innovation, which emphasizes dematerialized services over physical products in order to fulfill the functions offered by current products. Similar to function innovation, system innovation entails the development of new products and services, but with a focus on the entire socio-technological system; including products, production processes, enabling infrastructures and the institutional and social context. System innovation literature suggests societal experiments in protected niches as a useful management practice for promising technologies. This enables learning about the performance of new technologies and their economic viability, sustainability effects as well as social desirability (Kemp, Truffer, & Harms, 2000). Furthermore, some authors suggest that building upon the concept of business models, radical and system innovations can be addressed more effectively; since the business models can provide the link between micro and macro level perspectives, i.e. both firm and system level. In this view, business models are seen as a firm's ability in creating a fit between the characteristics of a technology and its commercialization in existing and new markets (Boons & Lüdeke-Freund, 2013).

Drawing on Brezet's categorization, Halila and Horte (2006) propose a similar typology of environmental innovations that include an additional set of criteria such as the degree of creativity and knowledge required as well as the extent of innovation (i.e. a component, product, a function within a system, or the whole system). This categorization involves six categories of innovations: product care, minor product improvement, major product improvement, functional innovation, system innovation and scientific breakthrough. Product care and minor product improvements entail the optimization of existing products or replacement of components, and require a standard or basic knowledge base within a company. Major product improvements involve fundamental changes, or completely new products that require a broader knowledge base linked to a specific industry branch that the product belongs to. Function and system innovations, as well scientific breakthroughs require a wide and extensive knowledge base, which in turn require the involvement of various actors. Such innovations potentially lead to the development of new systems and transform the knowledge field. From product care to scientific breakthroughs, the environmental impact of innovations is expected to improve by a factor of 2-3 up to 20 (Halila & Horte, 2006).

Besides the classifications that build on the degree of environmental impact, some scholars claim that the impact of eco-innovations depends not only on the degree of environmental impact, but also on the degree of market impact and success; which is related to the diffusion process of innovations. Combining the conventional innovativeness from a macro perspective and the eco-innovativeness from an environmental impact perspective, Hansen et al. (2011) propose an 'eco impact-innovativeness grid' (Figure 2.2). In this figure, the arrows suggest the potential development paths of innovations: from one cluster to the other. 'Mass market eco-innovation' is expected to influence markets or whole industries and create discontinuities on a macro level, thus it is very important for sustainability. By contrast, 'niche eco-innovation', which is mainly provided by sustainability pioneers, can have significant impacts on an aggregate level when they are multiplied by other firms. Furthermore, Hansen et al. (2011) add that the biggest challenge lies in moving conventional radical innovations towards the mass market eco-innovation cluster, which requires normative sustainability measures.

In summary, although the literature on sustainable innovation is fragmented with research focusing on products, technologies and society at large, the idea behind the eco-innovativeness continuum is similar to the conventional classifications presented in the previous section. From an environmental perspective, function and system innovations, which can be considered as really new and radical innovations in conventional terms, are considered to have the highest potential of environmental impact reduction (Hansen et al., 2011).

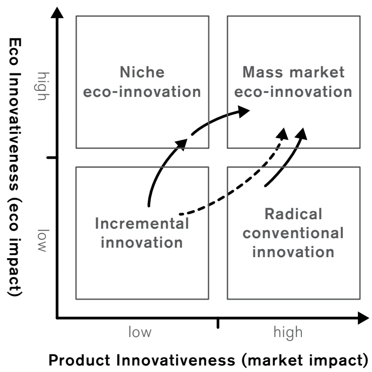


Figure 2.2. Eco impact-innovativeness grid (adapted from Hansen et al., 2011)

2.1.3. Conclusions

Literature offers a variety of perspectives on product innovativeness with different conceptualizations and operationalizations at various levels (i.e. macro and micro-level). Although the conventional and sustainability perspectives highlight innovativeness on the basis of newness of products and technologies, the main focus of sustainability scholars is the radicalness of an innovation based on the sustainability performance of the outcomes (i.e. products and services). In this regard, sustainable innovation literature offers various prescriptive tools and methods for designers and firms to redesign existing products, and develop new products with higher sustainability impacts. On the other hand, innovation management scholars are mainly concerned with the implications of different types of innovations and associated uncertainties for the innovation process. Accordingly, some scholars have criticized the (environmentally) sustainable product innovation literature for being largely normative and prescriptive, as well as failing to build on existing theoretical perspectives in innovation and organization studies (e.g. Baumann, Boons, & Bragd, 2002; Berchicci, 2005). Furthermore, other scholars have suggested that innovation is best understood by studying organizations and how managers experience it. In this respect, the fit between an innovation project and a firm's prior experience and skills are considered to be the most crucial factor for the practice of innovation (Tidd & Bodley, 2002). Therefore, on the basis of the criticisms above and the varying degrees of innovativeness in literature, developing new radical products that challenge existing practices are selected as the study object in this thesis.

Firstly, from the perspective of the firm, a radical innovation involves technology and market uncertainties, and requires firms to develop new skills and competences to reduce uncertainty; on the other hand, an incremental innovation does not involve high levels of technology and market uncertainties, and enables firms to build on existing competences.

Secondly, considering the expectation that necessary social and environmental changes for sustainability will be brought through new products that challenge existing practices, this study also focuses on the newness of an innovation from a customer perspective. As a result, whether or not an innovation is new to the world, market or industry, or whether it involves high levels of market uncertainty due to its newness to the customers, it is considered a radical innovation. Therefore, the radicality is defined as the firm's ability to develop and commercialize new products that are radically different from the currently available products. Radically new products are those that are new to both the firm and customers with a high degree of discontinuity from existing products. The firms' ability to introduce radically new products requires not only new technological, but also new marketing and other skills, knowledge or capabilities.

2.2. THE INNOVATION PROCESS

The nature of innovation and the organizational setting are likely to influence the innovation process. The innovation process for radical innovations that involve higher levels of uncertainty are likely to be less predictive and follow an unstructured process in comparison to incremental innovations (Van de Ven et al., 1999). In the following sections, the new product development (NPD) and radical innovation literature is reviewed, and various models of the innovation process are presented. In addition, characteristics of new ventures are discussed to draw conclusions for the question: how can the product innovation process be described within the context of new ventures?

2.2.1. Models of the innovation process

Although there is no single way to describe the innovation process (Buijs, 2003), many scholars within the field of innovation management have attempted to develop models for the innovation process. These models differ in terms of their underlying logic; the rational and non-rational view of the innovation process.

The rational models define a goal-oriented process: a problem is pre-defined at the outset of the process; for which alternative solutions are generated and the best solution is rationally chosen ex-post for further development. The innovation process is portrayed as an orderly linear process that consists of a sequence of phases. Each phase consists of diverging and converging activities that are aimed at generating various alternatives and selecting the best solution based on a set of requirements. The underlying idea behind the rational view is "Getting it right the first time" (Thomke, Von Hippel, & Franke, 1998). Therefore, prediction, planning and analysis are considered crucial for the successful development of new products. In this regard, early information gathering and rational analysis of this information are the basic first steps in defining a goal and developing a plan at the outset of the process.

Several innovation models within the fields of design and NPD support this notion. One of earliest design models developed by B. L. Archer (1971) includes six successive steps: strategic planning, research, design, development, manufacturing & marketing setup, and production. Similarly, The Delft Design Method, developed by Roozenburg and Eekels (1995), consists of diverging and converging steps of policy formulation, idea finding, strict development and realization (Figure 2.3). Each step consists of a sequence of analysis, synthesis, simulation and evaluation. The process starts with the analysis of the design situation, followed by a synthesis of possible solutions and a simulation in order to judge the possible solutions against the original design situation. The final step is the evaluation of the design solution. While the divergence is oriented towards getting as many alternatives as possible, the convergence is oriented towards choosing the best and most promising of those alternatives. In the Faculty of Industrial Design Engineering at TU Delft, specific design tools are taught to improve the performance of these diverging and converging activities (Buijs, 2003). Within the field of NPD, Cooper, et al.'s (2002) 'stage-gate' model suggests a similar logic (Figure 2.4). The model consists of: (1) a series of stages; in which various information gathering and analysis tools are utilized in order to reduce uncertainty, and (2) gates; in which decisions concerning to continue or abandon the projects are made based on a set of criteria.

In contrast to the rational view, the underlying assumption of the non-rational view is that the innovation is an inherently uncertain journey into the future. Accordingly, the innovation process may not start from a clearly defined goal and may not follow a straight line based on a plan (Schön, 1967). The product innovation process is portrayed as an iterative process of uncertainty reduction. An opportunity identified at the beginning of the process might not be the best one. Consequently, firms might need to engage in a series of iterations until a particular opportunity emerges. This implies that managers are confronted with decisions concerning shifts in goals and courses of actions, which require flexibility in the definition of products and markets. Within product development research, Eisenhardt and Tabrizi (1995) stress building flexible options as a way to deal with an unclear evolving market and technological space. Such an approach requires the development of multiple design options in the form of prototypes that build on previous design options or completely new alternatives. According to the authors, design iterations improve the product development process by increasing the chance of success, and by decreasing the development time, since design iterations provide the opportunity to judge and compare alternatives, as well as evaluate the robustness of designs. Furthermore, testing design options enables the developers to address problems in subsequent design iterations, decreasing the chances of error in the early phases of the process. Similarly, Thomke (1998) suggests 'design flexibility' as a way to effectively incorporate emerging information and tolerate late design changes. According to the author, a firm with less design flexibility is likely to engage in information gathering activities with an attempt to better understand customer needs, and consequently 'freeze' design specifications early in the process. This implies significant time and resource investment in the early phases, and the ignorance of any information that becomes available after such a freeze. On the other hand, design flexibility enables a firm to tolerate late design changes. Design flexibility can be achieved through rapid prototyping, which allows user feedback and development of products with fewer resources (Thomke, 1998).

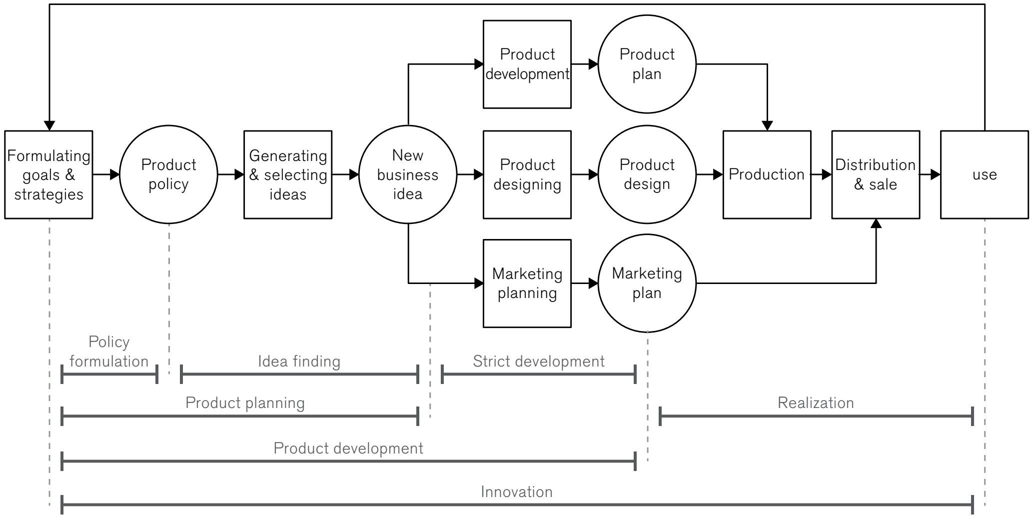


Figure 2.3. Structure of the innovation process (Roozenburg & Eekels, 1995)

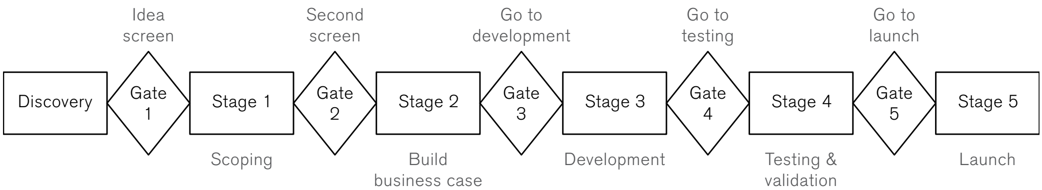


Figure 2.4. Stage-gate model (Cooper & Kleinschmidt, 2002)

The non-rational view suggests that the innovation process is an experimental learning process characterized by parallel paths of developments and intermediate outcomes (Van de Ven et al., 1999), unlike a single end product as proposed in rational models. Multiple applications and intermediate outcomes serve to reduce uncertainty through the generation of technical and market information. This way firms can learn and adopt based on emerging information. In summary, the non-rational view emphasizes learning and adaptation over analysis and prediction in reducing uncertainty. Therefore, the higher the uncertainties linked to an innovation, the more experimental and iterative the innovation process is likely to be (see Table 2.2).

Table 2.2. Differences between rational and non-rational views of the innovation process (based on Buijs, 2003; Cooper, Edgett, & Kleinschmidt, 2002; Roozenburg & Eekels, 1995; Schön, 1967; Thomke, 1998; Van de Ven, Polley, Garud, & Venkataraman, 1999)

	Rational	Non-rational
Mechanism	Analysis and prediction	Learning and adaptation
Goals	Predefined at the outset of the innovation process	Emerging along the process
Process	Linear and sequential	Iterative and non-linear with parallel paths
Main activities	Research and analysis	Experiments
Outcome	A successful single end product	Intermediate outcomes

2.2.2. The product innovation process in new ventures

In order to understand the innovation process, it is also vital to understand the organizational setting in which the innovation process unfolds. New ventures differ from large organizations mainly in two aspects: age and size. Due to these distinct characteristics, new ventures have particular strengths and weaknesses. Consequently, the innovation process in new ventures follows a different fashion in comparison to their larger counterparts.

The size related advantages of new ventures stem mainly from their structural simplicity, streamlined operations (Chen & Hambrick, 1995), and a lack of structural inertia (Hannan & Freeman, 1984). These characteristics enable small firms to possess a more responsive climate and quicker decision-making process (Damanpour, 2010) by being flexible (Fiegenbaum & Karnani, 1991), and taking rapid action in responding to evolving contingencies (Chen & Hambrick, 1995). Fast and informal communications, as well as an entrepreneurial management style are other frequently cited advantages; which enables small firms to react quickly to changing circumstances. Moreover, some scholars suggests that new organizations are more efficient in innovation since they are motivated to seek for opportunities to survive and challenge the status quo (Aldrich & Auster, 1986; Chen & Hambrick, 1995). New organizations are not hampered by residues from the past; in contrast to large organizations, which are less fit for changing environments and more prone to organizational inertia (Aldrich & Auster, 1986).

Despite these behavioral advantages, new organizations often suffer from limited resources , liabilities of newness (Stinchcombe, 1965), and liabilities of smallness (Freeman, Carroll, & Hannan, 1983). As a result, new firms are confronted with higher risks of failure (Aldrich & Auster, 1986). Due to being new and a lack of brand recognition, new firms face the challenge of product differentiation and market acceptance, which increases the market uncertainty and the need for financial resources such as advertising (Aldrich & Auster, 1986). Moreover, developing a new product for a new firm may entail higher costs due to the lack of scale and an established production system (Acs & Audretsch, 1987; Aldrich & Auster, 1986). These barriers, in turn, increase the technological uncertainty and the need for capital. Besides these additional costs, new firms do not often posses all the resources necessary for innovation development (Maillat, 1990) and face difficulties in raising capital (Aldrich & Auster, 1986). In order to overcome these shortcomings, they exploit networks to access to technologies and technological expertise, market knowledge as well as financial resources; however, they face other barriers in this acquisition process. New firms lack legitimacy as opposed to established firms, which might negatively influence market transactions and interactions with stakeholders (Damanpour, 1992). Thus, acquiring seed capital or venture capital is a challenge and often comes after a track record and at a cost, i.e. high interest rates, investors' expectations and demands, or giving up equity in the company to outsiders (Aldrich & Auster, 1986).

These distinct strengths and weaknesses can have a significant influence on the evolution of the product innovation process and the ability of new and small firms to engage in formalized NPD stage-gate processes. In fact, some scholars question whether this is a weakness, therefore by adopting a structured approach, small firms can be more successful; or the nature of small firms may call for a different approach (Berends et al., 2014). Based on a case study of five product innovation trajectories in small firms, Berends et al. (2014) suggest that small firms seldom engage in NPD best practices such as planning, upfront market research, or calculation of expected returns based upon prediction and analysis. Instead, the product innovation process of small firms is "resource-driven, stepwise and open-ended" (Berends et al., 2014). Small firms make decisions and engage in activities based upon limited and available resources, instead of predefined goals. The process follows an iterative stepwise fashion based on a loose project plan, as opposed to tight, formal procedures. Although the stepwise approach shares similar characteristics with stage-gate models, the decision moments and criteria are emergent. As a result, the feedback from customers, as opposed to predefined milestones, has a significant influence on subsequent decisions concerning resource allocation and commitment to a particular product definition. In fact, by developing concepts, prototypes and subsequent variations, small firms make decisions based on emergent circumstances. Consequently, small firms' product definition is not stable and evolves over time, in contrast to strict predefined goals. In other words, product innovation in small firms is open-ended, driven by a broad vision instead of concrete goals or well-defined product concepts (Berends et al., 2014). In a similar vein, Hürzeler (2013) suggests that due to the lack of financial, personnel and R&D resources, small firms seek out alternative approaches in order to reduce uncertainty in early phases of the innovation process. These approaches involve relying on existing knowledge, and making use of market intimacy instead of engaging in market research or large-scale planning efforts and activities, which require slack resources beyond the scope of small firms' budget (Hürzeler, 2013).

In fact, small firms apply radical innovation approaches even when they are engaged with incremental innovations (Berends et al., 2014). In other words, small firms' decision-making processes involve an iterative approach to uncertainty reduction, unstable product definitions and more flexible learning oriented approaches.

2.2.3. Conclusions

The development of radical sustainable products within entrepreneurial settings involves uncertainty in relation to supply and demand, as well as to the potential sustainability impact of innovations. Firstly, the nature of uncertainty on the supply side stems from the difficulty of translating technologies into applications, measuring the sustainability impact of new products, as well as acquiring the necessary resources for their development. Secondly, since new products depart significantly from currently available products, a potential customer's familiarity with existing products might lead to difficulties in articulating needs in relation to a new product (von Hippel, 1998). Hence, in the case of radical innovations, market uncertainty is related to which markets or segments are likely to value the innovation, rather than the size or potential of particular market segments (O'Connor, 1998). Furthermore, sustainability is a context dependent phenomenon; a product that is considered sustainable in a specific market segment might not be sustainable in another. As a result, sustainability-oriented new ventures are confronted with questions: which products to offer, for whom and with what environmental and social consequences. In the case of new ventures, uncertainties further stem from the limited resources and capabilities, as well as how to effectively put these in use.

Considering the challenges of new ventures and developing new sustainable products that depart significantly from currently available products, as well as the uncertainties linked to being small and new, the innovation process in new venture, is conceptualized in this thesis as an iterative learning process of uncertainty reduction.

2.3. MANAGING UNCERTAINTY

In the previous sections, various definitions of innovation were discussed, as well as the uncertainty linked to radical innovations and new ventures and their implications for innovation process. In this section, the way in which firms retain flexibility and learn to manage product innovation is discussed. Within the literature, various management approaches for managing uncertainty are discussed under terms like market experimentation, rapid prototyping, trial and error, and probe and learn. These approaches are characterized by an iterative process of learning through experimentation. In the following paragraphs, the most frequent referred three approaches to managing uncertainty, and the experiments used in practice are discussed to illustrate the various types of approaches and their learning effects.

2.3.1. Experimentation

Experimentation is a problem-solving activity in which an experiment creates a better understanding of a problem (Thomke, 1998) "for which outcomes are uncertain and where critical sources of information are nonexistent or unavailable" (Lee, Edmondson, Thomke, & Worline, 2004). Experiments provide decision-makers with the cognitive ability to adjust solutions based on new information that becomes available (Eisenhardt & Tabrizi, 1995). Therefore, experiments are instrumental in learning about the technical feasibility of a product idea and its market acceptance before committing substantial funds (Moore, 1982).

Experiments are "simplified versions of the eventually-intended test object" (Thomke et al., 1998). They are often conducted in controlled environments in order to decrease the cost of experimenting and simplify the analysis of the results by limiting the aspects of reality that are not relevant for the experiment. For instance, wind tunnel experiments of aircrafts are conducted with models that have no internal design details, which would increase the costs and are not relevant for the purpose of tests (Thomke et al., 1998).

The experimentation process is illustrated as an iterative cycle of learning in which design alternatives are generated, tested and evaluated (e.g. Simon, 1969; Thomke et al., 1998). Thomke's (1998) four-step iterative cycle portrays a good example of how an experimentation process unfolds (Figure 2.5).

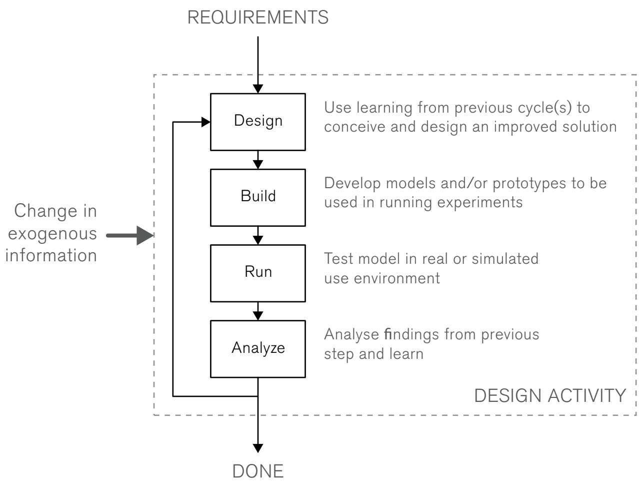


Figure 2.5. Experimentation as an iterative learning cycle (adapted from Thomke 1998)

It starts with the design of an experiment as a possible solution to a problem and proceeds with the development of a model or prototype, which is tested and analyzed in subsequent steps based on a set of requirements. Through an experiment, new information is generated that was not available or obvious at the outset of the process, e.g. an error that was not possible to know a priori (Eisenhardt & Tabrizi, 1995; Thomke et al., 1998). The outcome of an experiment might lead to a 'freeze' of the design requirements; or modification of the solution in subsequent experiments, which might even result in a change in 'the nature of the desired solution' (Thomke et al., 1998).

2.3.2. Trial and error

A single experiment is often not enough for problem-solving via experimentation. Problem-solving requires a series of experiments; i.e. a process of 'trial and error' learning (Garud & Van de Ven, 1992; Thomke et al., 1998). Unlocking a door with a set of unknown keys portrays a simple but good example of trial and error learning. Trying one key to unlock the door is a single trial. If this first trial opens the door, the experiment is successful and the trial and error process stops. If it fails, one can continue the experimentation process with a second key but this time with a narrower scope due to the information learned in the first trial (Lee et al., 2004). Although the term 'error' has a negative connotation, "Getting it wrong the first time" can actually be beneficial (Thomke, 1998). According to Thomke (2003, p. 27), "An innovation process … is at least partially based on 'accumulated failure' that has been carefully understood". A sequential approach to experimentation enables cumulative learning from one trial to another, influencing the subsequent decisions about the direction of innovation process (Silberzahn, 2011).

Applied to the product innovation process: if an experiment reveals satisfactory results, the trial and error process stops and the product can be introduced to the market (Lee et al., 2004). In this case, the definition of product-market (PM) combination does not change. If the outcome of an experiment is negative (e.g. technical failure or customers rejecting the product), the trial and error process continues. In this case, firms can choose to continue with the same PM combination based upon the information learned in the previous trial, or alternatively change the course of action, which might lead to a change in the definition of the PM pair.

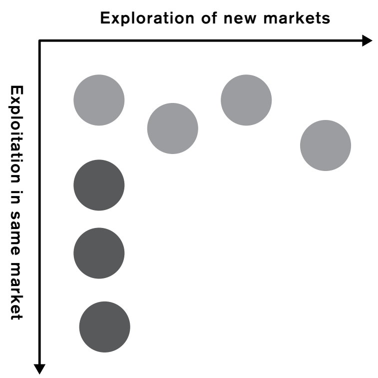
Although experimentation is a useful strategy for managing innovations that entail high levels of uncertainty, it provides limited learning (Silberzahn, 2011). Because experiments are often conducted with models in controlled environments, by limiting the aspects of reality, they have varying degrees of fidelity, i.e. the models are incomplete and the reality is not represented in its full dimensions (Thomke, 1998). Therefore, residual uncertainty can only be explored and solved when a product is introduced for the first time in a real environment, i.e. on the market (Thomke, 1998). In this regard, Lynn et al. (1996) propose experimenting in real markets through a 'probe and learn' approach.

2.3.3. Probe and learn

Another approach to managing uncertainty in radical innovations is 'probe and learn'; a term first coined by Lynn et al. (1996), who investigated the implications of radical innovations from a micro-managerial perspective. Although the underlying logic of probe and learn is experimentation, in this case the probe is not a trial as it is in the trial and error approach. In other words, probe and learn implies conducting experiments in real markets. It requires market experiments with immature versions of the products, i.e. "probing alternative markets with early versions of the products, learning from the probes, and probing again" (Lynn et al., 1996). As a result, probe and learn suggests a more effective management approach in comparison to trial and error in resolving market related uncertainties (Silberzahn 2011).

Moreover, a significant difference of the probe and learn approach from the rational models of product innovation process is that the initial product is only a first step and not the outcome of the development process. A probe in this process is a means for learning about the technology and markets. For example, through the probing process, firms learn about technologies and ways to scale them up, as well as which product features are interesting for a variety of market segments (Lynn et al., 1996). With a somewhat better understanding, firms might iterate again and again, i.e. engage in a process of 'successive approximation' until they arrive at a winning PM configuration. As a result, identifying a 'target market' at the beginning of the process may not be possible since the process of probe and learn "is a vehicle for identifying the target" (Lynn et al., 1996). The goal of probing is not to 'get it right the first time', but rather to maximize learning.

According to Hellman (2007), the probing process is particularly effective when there are multiple applications and markets to choose from; as a result, firms are confronted with decisions concerning probing in new markets and continuing in prior markets. The probing process, can thus be modeled by two different types of learning: explorative learning in new markets and exploitative learning in prior markets (Figure 2.6). After an exploration phase in a number of select markets, firms engage in exploitative probing, i.e. probing in prior markets



.Figure 2.6. Types of learning - circles represent the probes (adapted from Hellman, 2007)

2.3.4. Experiments in practice

The management practices described above point out the difficulty in making rational decisions based on only systematic information gathering, due to the high levels of uncertainty associated with radical innovations. Scholars have proposed various forms of experimentation in order to decrease the technical and market uncertainty. Experiments often encompass the embodiment of product ideas into physical applications. Experiments are the representation of potential solutions and are used to explore and communicate evolving ideas before fully committing to a particular artifact (Coughlan, Suri, & Canales, 2007). Depending on the purpose, experiments vary in terms of their resolution from low to high fidelity (Figure 2.7). Fidelity refers to the degree of accuracy to which an experiment represents reality (Thomke, 2008). The resolution of an experiment has implications for the speed and cost of an experiment, as well as the learning it provides.

Figure 2.7. Spectrum of experiments from low to high fidelity (based on Thomke, 2008)

Low-fidelity experiments such as mock-ups and models, are effective in early phases of the development; since they generate rapid feedback in validating designs, detect errors at low cost (McCurdy, Connors, Pyrzak, Kanefsky, & Vera, 2006; Thomke, 2008), reproduce rough functional properties, and are useful during the idea generation process (Pei, Campbell, & Evans, 2011). Low-fidelity experiments can be constructed with inexpensive and accessible materials in order to communicate the 'look and feel' of a particular idea, and explore both product-human interactions and how various mechanical elements work (Coughlan, 2007). However, as the innovation process unfolds, more accurate high-fidelity experiments such as working and production prototypes, become increasingly important; since low-fidelity models are often ineffective in detecting errors, which might lead to design failures (Thomke, 2008). High-fidelity experiments are useful for communication and verifying the final appearance and functionality of a product, as well as validating and confirming aesthetics and the technical performance of a product (Pei et al., 2011). Moreover, although they are cumbersome and expensive, high-fidelity experiments are often necessary in convincing stakeholders "that the real thing is indeed on its way" (McCurdy et al., 2006). In addition, as in the practice of probe and learn, an experiment might encompass the embodiment of an idea into an early version of the product with the purpose of experimenting in real markets.

In comparing low to high-fidelity; the cost and time to conduct experiments is likely to increase, as is the amount of technical and market learning. From an innovation process perspective, it is expected that the timing, drivers and type of experiments entrepreneurs engage in will vary both among firms and over time.

2.4. CONCLUSIONS

This chapter has discussed various typologies of innovation and their implications for the innovation process in order to answer the following research questions:

- How do new ventures manage the product innovation process? (RQ 1a)
- What actions drive the innovation process in new ventures, in particular the definition of product-market combinations? (RQ 1b)

Firstly, on the basis of the varying degrees of innovativeness, the decision is made to focus on radical innovation from a micro perspective, i.e. the newness of the product to both the firm and customer. In other words, an innovation is considered radical if it radically departs from currently available products, and requires firms to develop new skills and competences in order to reduce technological and market uncertainty. In the case of new ventures, uncertainties additionally stem from a lack of resources and capabilities to be able to engage in costly product development processes. Moreover, the nature of small firms appears to call for more flexible learning oriented approaches, as suggested by the non-rational view of the innovation process. Considering these arguments, it is concluded that new ventures are likely to apply radical innovation approaches. The innovation process in new ventures follows an iterative fashion, i.e. new ventures progressively define their PM combination over time based upon a series of experiments. Therefore, experimentation appears to be one of the crucial actions that drive the evolution of PM goals over time.

Through engaging in experiments, new ventures learn about the limitations and possibilities of a particular idea. Based upon the information learned, the experimentation process on a particular PM idea might stop (i.e. the product can be rolled out or abandoned), or continue in subsequent experiments. If a positive outcome is achieved through technological accomplishments or positive feedback from customers, the experimentation process is likely to stop and the firm continues with the same course of action (i.e. the same PM configuration). If a mixed or negative outcome is the result, the experimentation process is likely to continue. In this case, firms might continue with the same course of action or change it. In other words, the lessons learned can be used to design subsequent experiments for the same PM configuration, or lead to a shift in the definition of the PM pair. Therefore, product innovation process in new ventures can partly be captured by describing the way in which new ventures experiment with their PM ideas.

In addition, as discussed in section 2.2, it is expected that product innovation that is built on new technologies, involves higher uncertainties in comparison to products that are built on existing technologies. This stems not only from the need for highly skilled employees, which increases the cost of experiments, but also from the difficulty of translating a new technology into applications. In the case of new technologies, the experimentation process is likely to involve higher number of trials with mixed or negative outcomes, and might consequently lead to higher number of shifts in product concepts and/or target segments. As a result, this study assumes that the newness of technology is likely to influence the experimentation process in a significant way.

In the following chapter, the entrepreneurship literature is reviewed to further identify the actions that drive the product innovation in new ventures. In other words, besides the experiments, what other actions drive the evolution of PM definitions? Additionally, the concepts from entrepreneurial decision-making and behavior as well as the factors influencing the decision-making process will be discussed to further conceptualize the product innovation process in new ventures.

Chapter 3

Entrepreneurial Decision-Making and Behaviour

The previous chapter presented a range of concepts in the field of innovation management. The purpose of this chapter is to set forth the theoretical background by introducing a range of concepts in the area of entrepreneurship with a focus on entrepreneurial decision-making and behavior, in order to understand how new ventures manage the process of new product innovation. Entrepreneurial decision-making theories offer a suitable perspective in explaining the firm behavior and the patterns of product innovation process among new ventures. They provide an interpretive lens to better understand the factors that influence firm behavior. Therefore, this chapter aims to address the following questions:

- What actions drive the innovation process in new ventures, in particular the definition of product-market combinations? (RQ 1b)
- What factors influence the product innovation in new ventures? (RQ 2a)

The first section of this chapter presents a brief historical account of the definitions and concepts that have emerged from various disciplines that have studied entrepreneurship (3.1). The next section focuses on the opportunity construct and presents the recent scholarly debate on the process of opportunity identification (3.2). Subsequently, the entrepreneurial decision-making paradigms in relation to opportunity identification are discussed under the 'causation-effectuation' dichotomy, which provides a suitable lens in understanding the dynamics of entrepreneurial process (3.3). Section 3.4 presents the behavioral implications of these contrasting theoretical perspectives, and various factors that might explain the evolution of the entrepreneurial process. Finally, particular implications for the product innovation process are discussed (3.5).

3.1. EVOLUTION OF THE FIELD

Entrepreneurship is a multidisciplinary field of scholarly interest, which draws from various disciplines such as economics, sociology, psychology, marketing, organizational learning and strategic management. The growing body of research on entrepreneurship offers a complex and fragmented body of literature. Nevertheless, 250-year-old entrepreneurship research has mainly revolved around the unique function of entrepreneur within the economy (*what* is the function of the entrepreneur?), and the unique characteristics of individuals in performing this function (*who* is the entrepreneur?) (Parrish, 2007), at the same time, mostly ignored the process of opportunity identification (*how* do entrepreneurs identify opportunities?) (Shane & Venkataraman, 2000).

In order to understand the essence of entrepreneurship, it is important to provide an insight into this fragmented body of literature by presenting an overview of the various schools of thought that have studied entrepreneurship thus far. According to Deakins and Freel (2003), three dominant approaches exist to studying entrepreneurship: 1) the economic approach, 2) the psychological approach and 3) the socio-behavioral approach (Figure 3.1). This section provides a brief historical account of the field based on Deakins and Freel's categorization. Subsequently, the research stream on the process of opportunity identification is presented (3.2).

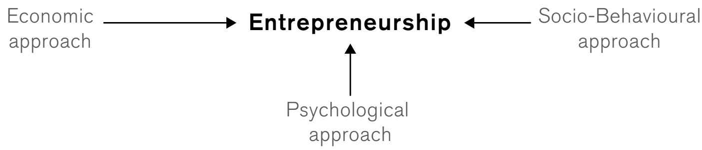


Figure 3.1. Dominant approaches in entrepreneurship research (adapted from Deakins and Freel 2003, p.2)

3.1.1. Economic approach

The earliest contributions to the field of entrepreneurship came from economists who mainly studied the role and function of entrepreneurs within the large economical system, and attempted to explore the impact of entrepreneurial output on the economic development (Bruyat & Julien, 2001; Hindle & Al-Shanfari, 2011). Since Richard Cantillon first coined the term 'risk-bearing' to define entrepreneurs in 1775, scholars have debated on the role of risk and its links to the entrepreneur and economical system (Stevenson & Jarillo, 2007). For instance, Knight (1921) distinguished between risk and uncertainty: "In the former, the distribution of the outcome in a group of instances is known (either through calculation a priori or from statistics of past experience), while in the case of uncertainty this is not true, the reason being in general that it is impossible to form a group of instances, because the situation dealt with is in a high degree unique". According to Knight (1921), an entrepreneur is well-equipped for uncertainty, and his abilities lie in controlling the productive powers responsibly through the exercise of judgment in an uncertain future. Schumpeter (1934), on the other hand, focused on innovation as the essential function of entrepreneurs, rather than their attitude towards risk. The Schumpeterian entrepreneur, therefore, can be any person who disrupts the market equilibrium through 'carrying out new combinations' creatively in an effort to introduce a new product, a new method, a new organization or a new market (Schumpeter, 1934). In this view, entrepreneurs are 'innovators' who engage in a process of 'creative destruction' and make 'conventional ways of doing' obsolete.

Another popular debate among economists concerns the state of markets and the role of entrepreneurs within the market system. The initial interpretations were based on equilibrium models of economics. Equilibrium models assume that markets are in a state of equilibrium, or would eventually reach equilibrium; thus "No one can discover a misalignment that would generate an entrepreneurial profit because, at any point in time, all opportunities have been recognized and all transactions perfectly coordinated" (Shane & Venkataraman, 2000). As a result, equilibrium theories are criticized for assigning no significant role for the entrepreneur (Bianchi & Henrekson, 2005; Shane, 2000). On the other hand, the more recent disequilibrium perspective attributes a more active role to the entrepreneurs. While Schumpeter claimed that entrepreneurs create disequilibrium in the market system through innovation, Kirzner (1997) stated that entrepreneurs move the markets from a state of disequilibrium to equilibrium. According to Kirzner (1997), the role of entrepreneur is to discover pre-existing opportunities in an effort to bring the market to equilibrium. In order to discover opportunities, one must be 'alert' to possibilities, and thus 'alertness' is what sets entrepreneurs apart from non-entrepreneurs.

3.1.2. Psychological approach

The disequilibrium models have been criticized for their focus on entrepreneurial function, and the view of the theoretical firm 'entrepreneurless' has given rise to a number of studies in order to understand why some individuals start entrepreneurial ventures, which entails a great deal of risk with high rates of failure (Bianchi & Henrekson, 2005; Busenitz, 1999). Some scholars have advocated studying the differences between entrepreneurs and non-entrepreneurs, and have examined the psychological and personal/demographic differences. Early research on individual entrepreneurs is referred to as 'traits approach', which was a predominant approach in 1970s and 80s. Scholars in this domain focused on a number of psychological characteristics to describe the types of people that engage in entrepreneurial activity (Eckhardt & Shane, 2003). For instance, McClelland (1967) highlighted the 'need for achievement' as a crucial factor for entering entrepreneurial occupations; and Hornaday and Aboud (1971) studied a number of personal characteristics associated with successful entrepreneurs. Besides the need for achievement, the traits approach resulted in a set of individual characteristics such as commitment to work (McClelland, 1967), risk management (Palmer, 1971), self-reliance, competitiveness, versatility and resilience (Hornaday & Aboud, 1971), need for power (Winter, 1973), internal locus of control (Brockhaus, 1982) and tolerance to ambiguity (Schere, 1982; Sexton & Bowman, 1986). This person-centric view has been criticized for attempting to explain entrepreneurship through stable, enduring differences among people that are independent of the context they navigate through (Eckhardt & Shane, 2003; Shane & Venkataraman, 2000). This view has also been criticized for not offering answers to the act of 'entrepreneuring' (Deakins & Freel, 1998); thus, failing to explain the causal relationships or implications for practice (Low & MacMillan, 1988). Furthermore, the differences among entrepreneurs are as large as the differences between entrepreneurs and non-entrepreneurs (Gartner, 1985), which makes it difficult to develop a standard psychological profile of the entrepreneur (Low & MacMillan, 1988). For instance, Brockhaus (1980) did not find significant differences between entrepreneurs and the rest of the population in terms of risk propensity.

The paradox that entrepreneurs take more risk but do not have a higher risk propensity has given rise to a number of studies that examine individual entrepreneurs from the lens of cognitive psychology and decision-making (Busenitz 1999). This is the most recent reincarnation of the psychological approach, which highlights the relevance of cognitive processes for entrepreneurship. The entrepreneurial context characterized by uncertainty makes it particularly important to study the perception, information processing as well as decision making of entrepreneurs (Forbes, 1999). Among others, scholars in this domain have attempted to investigate the unique aspects of entrepreneurs' cognitive processes such as the use of heuristics and bias in entrepreneurial decision-making (Kahneman & Lovallo, 1993; Busenitz 1999; Sarasvathy 2008), the link between entrepreneurial cognition and opportunity identification (Shane, 2000), the role of creativity in generating innovative business ideas (Ward, 2004), the role of intentions in predicting the behaviors of entrepreneurs (Bird, 1988) and more recently, the motivation of entrepreneurs in triggering action (Carsrud & Brännback, 2011). For instance, internal drives such as the 'need for achievement' are likely to increase the degree of entrepreneurial intentions (Solesvik, 2013), and some external incentives such as income or prestige are likely to transform intentions into actions (Fayolle, Liñán, & Moriano, 2014). Shane and his colleagues have examined the link between motivations, opportunities and the entrepreneurial process, and have argued that entrepreneurs differ in how they interpret and exploit an opportunity. The same opportunity might result in different decisions and actions based on the motivations of the entrepreneurs (Shane et al., 2003). Moreover, Shane et al. (2003) drew attention to studying motivations from a dynamic evolutionary perspective, rather than adopting static research designs. For instance, a high need for achievement is likely to influence obtaining venture capital, while it might have no significant effect on the subsequent phases of the entrepreneurial process (Shane et al., 2003).

According to the psychological approach, perception and motivation of entrepreneurs are crucial factors to understand the entrepreneurial process; since decisions are driven by the subjective assessment of entrepreneurs such as values, norms and beliefs, rather than the objective contextual factors (Ajzen and Fishbein, 1980; Penrose, 1959 as cited in Edelman & Yli-Renko, 2010). Likewise, Sarasvathy (2001a) argues that entrepreneurs driven by an aspiration or an idea take action based on subjective expectations of some imagined ends, in order to construct the future.

3.1.3. Socio-behavioral approach

Moving away from the traits approach, some scholars emphasized the social dimension and behavioral aspects of entrepreneurship. Initially, studies examined the external causes of entrepreneurial behavior (Busenitz & Barney, 1997). The externally-oriented work examined correlations between socio-cultural variables with entrepreneurial variables. For instance, Shapero and Sokol (1982) argued that social institutions affect the perceptions of desirability and feasibility of entrepreneurial activities. Cultural norms and values as well as governmental policies are found to influence environmental intentions and creation of niches, which are more attractive to entrepreneurs and investors (Aldrich & Zimmer, 1986). Birley (1985) examined the role of networks for new ventures and found that informal contacts of family, friends and colleagues are the main sources in assembling resources in the start-up process.

Research on networks thus far have produced important insights on the link between a number of network variables and entrepreneurial outcomes (Hoang & Antoncic, 2003). These studies highlight the social 'embeddedness' of entrepreneurs, a term first coined by Aldrich and Zimmer (1986). Adapting an evolutionary perspective, Aldrich and Martinez (2001) emphasized the interactions between process, context and outcome, and recommended studying "the creation of new organizational structures (variation), the way in which entrepreneurs modify their organizations and use resources to survive in changing environments (adaptation), the circumstances under which such organizational arrangements lead to success and survival (selection), and the way in which successful arrangements tend to be imitated and perpetuated by other entrepreneurs (retention)." In a similar vein, Gartner (1985) developed a framework to describe new venture creation (Figure 3.2), suggesting that the process of new venture creation is a multidimensional phenomenon and the differences between processes can be explained by a combination of variables. These variables are grouped into four dimensions: 1) individuals – the person(s) involved in the creation of new venture, 2) organization – the type of firm founded, 3) environment – the context influencing the new organization, and 4) process – actions taken by the individual to start the venture. The similarities and differences among new venture creation processes can thus be explained by the interplay of factors in each dimension (Gartner, 1985). More recently, with an emphasis on viewing entrepreneurship as a process, Baron (2002) proposed a model of entrepreneurial behavior driven by three groups of factors: (1) individual factors (e.g. motivations, attitudes, cognitions, knowledge), (2) interpersonal factors (e.g. influence of family, friends, cultural values), and (3) societal factors (e.g. government policy, economic factors). He argues that the relative importance of these factors vary over time during the venturing process.

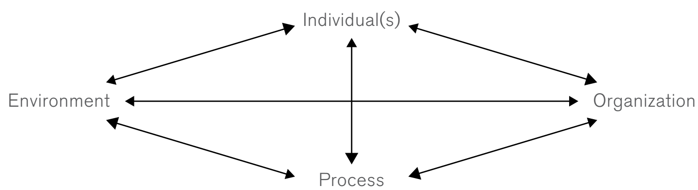


Figure 3.2. Gartner's framework for describing new venture creation

In addition, moving away from contextual factors, which fail to explain why some individual entrepreneurs identify and exploit opportunities and others not, a body of research has focused on the individual level behaviors associated with new venture and business creation, in order to define a number of acts that distinguish the phenomenon of entrepreneurship (Busenitz & Barney, 1997): *what* entrepreneurs do. Entrepreneurial behavior is highlighted as an important construct in understanding the entrepreneurial process (Bird & Schjoedt, 2009). The behavior construct is defined as "the concrete, theoretically observable actions of individuals in the start-up or early stages of organization creation" (Bird, Schjoedt, & Baum, 2012). While cognitive processes are invisible, behaviors are observable (Bird & Schjoedt, 2009) and "constitute actions that can be recorded on audio or video and can be obtained from credible self-reports" (Bird et al., 2012). As an example, planning encompasses both cognitive and behavioral aspects, in which writing and communicating a plan are observable actions, thus constituting behavior. The focus of this research stream is to explain and predict both individual and team level behaviors (Bird et al., 2012).

In a review of recent entrepreneurial behavior research (based on 91 articles published between 2004 and 2010), Bird and her colleagues (2012) list a number exemplar entrepreneurial behaviors such as problem solving, approaching investor, communicating with customer, debating decision, planning marketing, improvising, acquiring information, identifying ideas, interacting with external agents and improvising. While some of these studies treat behaviors as dependent variables, others treat them as independent variables. The recent examples of empirical studies treating behaviors as dependent variables investigated a number of factors (e.g. demographic variables, gender and entrepreneurial expertise) and their influence on behaviors (e.g. opportunity identification, start-up activities, etc.) (DeTienne & Chandler, 2007; Ucbasaran, Westhead, & Wright, 2009). Those studies using behaviors as independent variables examined the links between a number of behaviors (e.g. improvising and resources combinations activities, improvisational behavior, etc.) and entrepreneurial variables (e.g. new venture performance, work satisfaction, the legitimacy of emerging organizations, etc.) (Hmieleski & Corbett, 2008; Tornikoski & Newbert, 2007). For instance, based on a quantitative study on 109 nascent entrepreneurs, Lichtenstein, Carter, Dooley, and Gartner (2007) investigated the link between the dynamics of a number of startup activities and the emergence of new firms, concluding that the rate of firms' emergence are positively correlated with the rate of activities that were conducted later in the process. Ucbasaran her colleagues (2009) examined the influence of prior business ownership experience on the opportunity identification process, and found that experienced entrepreneurs identified higher number of opportunities and exploited more innovative opportunities in comparison to novice entrepreneurs.

3.1.4. Conclusions

This section has reviewed the entrepreneurship literature based on three dominant approaches that studied entrepreneurship over time: 1) the economic approach, 2) the psychological approach and 3) the socio-behavioral approach. Scholars have studied entrepreneurship from different angles, as well as with different approaches and units of analysis. Recent studies and insights have suggested that entrepreneurship is about action, and in order to understand the dynamics of *how* entrepreneurs do *what* they do, entrepreneurship research should focus on entrepreneurial behavior and process. Furthermore, entrepreneurship can be understood as a process in which the entrepreneurs' actions have both cognitive and social dimensions. Based on the synthesis of these ideas, entrepreneurship in this study is defined as '*a process of opportunity identification, in which entrepreneurs translate their initial intentions, motivations and prior knowledge into new organizations through their actions and interactions with others*'.

3.2. OPPORTUNITY IDENTIFICATION

Having briefly discussed the evolution of entrepreneurship research, this section focuses on the process of opportunity identification, in line with the questions raised at the beginning of this chapter. The opportunity construct is important in this study for two reasons. Firstly, it is comparable to the innovation construct in innovation literature, which was extensively discussed in section 2.1. Just like innovations, opportunities can be of different nature and are characterized by risk and uncertainty. The literature on how opportunities are identified offers a useful perspective for understanding similarities and differences in the entrepreneurial process, in particular the decision-making process of entrepreneurs and their the behavioral implications. Secondly, different decision-making theories are likely to offer different explanations of how the process of opportunity identification evolves, which is relevant to the second research question that was raised at the beginning of this chapter.

In their attempt to define a distinctive domain of entrepreneurship, some scholars have recently drawn attention to the process of entrepreneuring and the role of opportunities in this process (Eckhardt & Shane, 2003; Venkataraman, 1997). The research on opportunities revolves around the following three questions: "(1) why, when, and how opportunities for the creation of goods and services come into existence; (2) why, when, and how some people and not others discover and exploit these opportunities; and (3) why, when, and how different modes of action are used to exploit entrepreneurial opportunities" (Shane & Venkataraman, 2000: 218). These questions distinguish between sources of opportunities, individual differences and the types of actions taken by entrepreneurs. For instance, Venkataraman (1997) states that knowledge differences, cognitive differences and behavioral differences strongly influence the process of opportunity identification and exploitation. The previous section presented a brief overview of prior entrepreneurship research, which extensively studied these differences. Accordingly, three distinct theoretical perspectives on how entrepreneurs identify and exploit opportunities exist: (1) recognition view, (2) discovery view, and (3) creation view. The recognition view is based on early theories of economic approach, which assumes that markets are perfectly competitive and in equilibrium. The economical actors are perfectly informed, which implies that all market participants "are equally likely to detect a given opportunity; opportunity recognition is thus a purely random process" (Sarasvathy, Dew, Velamuri, & Venkataraman, 2010: 87). Hence, focus is given to the economical system rather than the individuals. Opportunities, in this view, are conceptualized as a resource allocation problem of existing supply and demand. In other words, "if both sources of supply and demand exist rather obviously, the opportunity for bringing them together has to be 'recognized', and then the match-up between supply and demand has to be implemented either through an existing firm or a new firm. This notion of opportunity has to do with the exploitation of existing markets" (Sarasvathy et al., 2010: 81). The discovery view and creation view, on the other hand, build upon subsequent interpretations of economic approach, which claims that markets are in a state of disequilibrium and opportunities emerge from competitive imperfections (Alvarez, Barney, & Anderson, 2013). This means that knowledge or information is dispersed and divided among individuals in a way that no two individuals posses the same information about the market, industry or economy (Venkataraman 1997). However, the discovery and creation views differ significantly in terms of their assumptions about the sources of competitive imperfections, the nature of opportunities, the nature of entrepreneurs and the nature of the decision-making context (Table 3.1), which are elaborated in the following paragraphs.

Table 3.1. Central assumptions of discovery and creation view of opportunities (based on Alvarez & Barney, 2007; and Alvarez & Barney, 2013)

	Discovery view	Creation view
Sources of competitive imperfections	Objective opportunities formed by exogenous shocks to existing markets and industries	Enacted opportunities formed endogenously by entrepreneurs seeking to exploit them
Nature of opportunities	Opportunities exist independent of entrepreneurs	Opportunities do not exist indepen-dent of entrepreneurs
Nature of entrepreneurs	Differ in some important way from non-entrepreneurs, ex ante	May or may not differ from non-en-trepreneurs, ex ante. Differences may emerge, ex post
Nature of decision making context	Risky	Uncertain

3.2.1. Discovery view

Moving away from equilibrium theories (refer to 3.1.1.), the discovery view of opportunity has received considerable attention in entrepreneurship research. The discovery view has its roots in the works of Austrian economists such as Menger, Hayek and Kirzer, who, in a nutshell, suggest the following assumptions: (1) opportunities (i.e. unmet needs) exist independent of entrepreneurs, (2) individuals possess different information or knowledge, which enables them to see particular opportunities that others are not able to see, and (3) entrepreneurs differ from non-entrepreneurs (Alvaraz & Barney, 2013).

Following Menger, supporters of the discovery view propose that opportunities are objective realities that stem from competitive imperfections, and are waiting to be discovered by an entrepreneur; “they are like lost luggage at a train station, waiting to be claimed by some unusually alert individual” (Alvarez et al., 2013). The claim that ‘opportunities are real and exist’ follows a critical realist epistemology, which suggests that “part of what determines the way the world actually is, is the structure of opportunities in the world – opportunities that alert individuals can discover” (Alvarez & Barney, 2013). Thus, opportunities exist independently from both entrepreneurs’ perception and actions, or whether entrepreneurs decide to exploit them or not.

Concerning sources of opportunities, Schumpeter argued that imperfections arise from exogenous shocks, such as changes in technology, customer preferences, regulatory environments and others (Eckhardt & Shane, 2003). The new information that is generated through shocks influences the price of resources, and enables entrepreneurs to create new products and services based upon this information. On the other hand, in line with Hayek's proposition that information is heterogeneously distributed among economic actors, Kirzner suggests that opportunities arise from asymmetries in information possessed by individuals, leading some individuals to recognize opportunities and others not (Alvaraz & Barney, 2013). Furthermore, individuals hold beliefs based on the information they posses. These beliefs might lead economic actors to make mistakes; entrepreneurs who are alert to these mistakes can capitalize on them (Shane & Venkataraman, 2000). Whether opportunities are discovered through new information generated or asymmetries of information and beliefs, the common assumption is that they arise from existing markets and industries (Alvaraz & Barney, 2013).

Similar to the discontinued traits approach (refer to 3.1.2), entrepreneurs are conceptualized as being different to non-entrepreneurs. However, differences lie in the dynamic cognitive processes that enable entrepreneurs to see opportunities that others are not able to see. Most notably, Kirzner suggested 'alertness' in distinguishing entrepreneurs from others. According to Kirzner (1997), entrepreneurial alertness is "an attitude of receptiveness to available (but hitherto overlooked) opportunities". Busenitz and Barney (1997) found empirical evidence that entrepreneurs and managers in established organizations utilize 'biases and heuristics' at varying degrees. Shane (2000) argued that the cognitive process is conditioned by 'entrepreneurs' prior knowledge of markets, prior knowledge of ways to serve markets and prior knowledge of customer problems'. Although cognitive differences have been systematically found, the research is inconclusive on whether these cognitive differences are the cause or consequence of entrepreneurial actions (Alvaraz & Barney, 2007).

Finally, the discovery view conceptualizes the decision-making context as being risky rather than uncertain, as distinguished by Knight (1921) (refer to 3.1.1). Sarasvathy (2008) explains the difference between risk and uncertainty through the urn metaphor: "Consider first a game in which you draw balls from an urn containing five green balls and five red balls. If you draw a red ball, you win $50. For any given draw, you can calculate precisely the probability of getting a red ball, because you know the distribution of balls in the urn. This kind of game is an example of risk. Now consider a game in which you are again awarded $50 for drawing a red ball, but this time you do not know how many balls are in the urn, what colors they are, or if there are any red balls at all. This kind of game exemplifies uncertainty. In statistical terminology, decisions involving the first type of urn with the known distribution – a situation characterized by risk – call for classical analytical techniques; and the decisions involving the second type of urn with the unknown distribution – a situation characterized by uncertainty – call for estimation techniques." Therefore, a risky decision-making context implies that entrepreneurs can increase the chances of discovering opportunities by applying systematic data collection and analysis techniques to understand the possible outcomes of an opportunity (Alvarez & Barney, 2007). The underlying logic is: "To the extent we can predict future, we can control it" (Sarasvathy, 2001a).

3.2.2. Creation view

While the discovery view proposes cognitive abilities and possession of particular information and knowledge as the determinants of opportunity identification, the creation view emphasizes the importance of certain behavioral patterns that enable entrepreneurs to create opportunities. Following social constructionist and evolutionary realist traditions, the creation view suggests that opportunities "are formed endogenously by the actions of those seeking to generate economic wealth themselves" (Alvarez & Barney, 2013). Thus, opportunities do not arise from pre-existing markets and industries (Alvaraz & Barney, 2007); instead they "emerge out of the imagination of individuals by their actions and their interactions with others" (Gartner, Carter, & Reynolds, 2010: 114). The sources of opportunities are, therefore, the actions of the entrepreneurs without which opportunities would not exist.

The creation view, therefore significantly differs from the discovery view in conceptualizing the relationship between the individual and the opportunity. In the creation view, the individual and the opportunity are not separate and distinct but interdependent constructs (Sarason, Dean, & Dillard, 2006). For instance, building on Gidden's structuration theory, Sarason et al. (2006) suggest that opportunities, entrepreneurs and social systems co-evolve from the recursive venturing processes. As entrepreneurs engage in the venturing process, opportunities are constructed and reconstructed through entrepreneurs' actions and interactions (Sarason et al., 2006).

Furthermore, unlike the discovery view, cognitive or personal differences are not the determinants but the result of who engages in the enactment process of opportunities. (Alvarez & Barney, 2013). By engaging in the venturing process, entrepreneurs develop particular cognitive patterns and heuristics, which can be observed in experienced entrepreneurs (Hayward et al., 2006). Along that line, Sarasvathy (2001a) investigated the differences between experienced and novice entrepreneurs, and suggested that experts use a different decision-making logic, which she labeled as 'effectuation'. The expert entrepreneurs are consequently more likely to engage in the process of opportunity creation. Baron and Ensley's (2006) study on the patterns of opportunity recognition between novice and experienced entrepreneurs support this argument. According to Baron and Ensley (2006), entrepreneurs acquire distinct cognitive patterns through experience, which provide them "with a basis for noticing connections between seemingly independent events or trends (e.g. advances in technology, shifts in markets, and changes in government policies), and for detecting meaningful patterns in these connections." Empirically, they have found that expert entrepreneurs perform better in 'connecting the dots' between unrelated events and trends in developing ideas for new products and services.

Lastly, the decision-making context in the creation view is characterized by, what Knight (1921) referred to as 'true uncertainty'. This implies that historical information and objective knowledge about opportunities do not exist (Alvarez & Barney, 2013). In other words, the decision-making context entails a future that is "not only unknown, but unknowable even in principle" (Sarasvathy, 2008). For situations in which calculating the probability of the outcomes is impossible (e.g. the urn metaphor), systematic data collection and analysis techniques become irrelevant. Instead, by acting and co-enacting with others, entrepreneurs generate new information and obtain diverse knowledge that may be combined to create novel ideas (Alvarez & Barney 2013). The rationale behind the creation view is: "To the extent we can control future, we do not need to predict it" (Sarasvathy, 2001a).

3.2.3. Conclusions

The debate on how opportunities identified is mainly theoretical and conceptual, nevertheless useful. The discovery view has received much attention among scholars, which is reflected in the entrepreneurship research and education (Sarasvathy, 2001a). On the other hand, the creation view has long lacked a coherent theory and empirical ground (Alvarez & Barney, 2007). New perspectives based on the creation view are still emerging, such as Baker's entrepreneurial bricolage and Sarasvathy's effectuation. For instance, Baker and Nelson (2005) argue that firm survival and success cannot be explained based only on the view of an objective resource environment. The social construction of resources has a significant influence on the behavior of firm, i.e. the entrepreneur engages in a process called bricolage in order to "make do by applying combinations of the resources at hand to new problems and opportunities" (Baker & Nelson, 2005). In this view, entrepreneurs focus on existing resources instead of buying or fabricating new resources. In a similar vein, Sarasvathy (2008) has contributed to the creation view with the theory of effectuation. Building on the work of Knight (1921) regarding uncertainty, Sarasvathy (2008) argues that expert entrepreneurs focus on creating effects based on a set of available means, and engage directly in a series of actions and interactions. The driving mechanism of the entrepreneurial process is stakeholder commitments. Another perspective worth mentioning here is the 'user entrepreneurship', as suggested by Shah and Tripsas (2007), which is defined as "the commercialization of a new product and/or service by an individual or group of individuals who are also users of that product and/or service". In contrast to classic models of entrepreneurship (i.e. the discovery view), the user entrepreneurship process is emergent based on feedback and adaptation that occurs even before an opportunity is identified or a firm is founded. In other words, opportunities emerge from the actions undertaken by users (e.g. user experiments and interactions with the public and user communities) in order to satisfy their own needs.

In this study, focus is given to Sarasvathy's logic of effectuation, because effectuation:

- generates the greatest scholarly response* in literature;
- is contrasted with the traditional perspectives (under the label 'causation') in great detail, and offers explanations as to why entrepreneurs are likely to use a causal versus effectual logic;

** A search on Google Scholar on May 22, 2015 revealed 2019, 1185 and 258 citations for Sarasvahy (2001), Baker and Nelson (2005), and Shah and Tripsas (2007), respectively.*

- offers a dynamic perspective on the entrepreneurial process, whereas bricolage and user entrepreneurship describe the process through stage models;
- offers 'general to all' explanations, while bricolage is strongly associated with 'resource-poor environments' (Moroz & Hindle, 2012), and user entrepreneurship with individuals who are simultaneously both users and entrepreneurs;
- describes a problem space characterized by uncertainty and a decision-making logic that is suitable in addressing uncertainties linked to radical innovations, sustainability and new ventures;
- captures the aspect of embeddedness and social dimension of the entrepreneurial process through stakeholder interactions and negotiations;
- stresses creativity and imagination that makes it especially suitable for studying the new product development processes, which are inherently creative.

Further argumentation of this choice for the effectuation perspective will be dealt with in the next paragraph.

3.3. EFFECTUATION

Based on the cognitive study of Sarasvathy (2001a) on entrepreneurial expertise, effectuation has been developed as an alternative to the rational economic theories of decision-making, which defines a causal process. Sarasvathy's work was inspired by Knight (1921), who distinguished between 'risk' and 'uncertainty' (refer to 3.1.1), as well as Simon (1955), who argued that the human mind has limits to information processing, particularly in situations of uncertainty and where decision-makers are 'rationally bounded'.

The aim of Sarasvathy's research was to explore the learnable and teachable aspects of entrepreneurship through investigating the decision-making logic of expert entrepreneurs in transforming an idea into a new business, particularly in cases where markets do not pre-exist. Her research design included a 'think-aloud' protocol, in which 30 entrepreneurs were asked to build a company based on the same product idea and ended up developing firms in 18 different industries. Sarasvathy (2001a) found empirical evidence that expert entrepreneurs use a distinctive set of decision-making principles: 'effectual reasoning'. Effectuation is the inverse of traditional theories of causal rationality, which assume that goals can be predefined at the outset of the entrepreneurial process on the basis of historical information, enabling predictions about the future. In an effectual problem space, however, the process does not start with clearly specified goals, and often ends with unimagined effects (Dew, Read, Sarasvathy, & Wiltbank, 2008). Sarasvathy (2008) argues that the use of effectual logic is more suitable in cases of Knightian uncertainty, in which the future is "not only unknown but unknowable even in principle". In contrast, causation is more suitable for situations characterized by risk.

This section presents an overview of the definitions for causation and effectuation and their comparison, the principles and process dynamics of effectuation, and empirical studies based on effectuation as well as its behavioral implications.

3.3.1. Causation versus effectuation

Effectuation is the inverse of causation (i.e. predictive reasoning), which is predominantly taught in business (Sarasvathy, 2001a) and design schools. Unlike causation, which is linked to planned strategy approaches and involves activities such as opportunity recognition, research, analysis and planning, effectuation is linked to emergent strategy approaches, in which the alternatives are chosen based on a set of effectual principles (Chandler et al., 2011). Sarasvathy (2001a) defines a casual process as “taking a particular effect as given and focus on selecting between means to create that effect”. On the contrary, in an effectual process, entrepreneurs “take a set of means as given and focus on selecting between possible effects that can be created with that set of means” (Figure 3.3). Sarasvathy (2001a) explains the difference between two approaches in an example of a chef cooking dinner. In a causal approach, the chef would develop a list of ingredients necessary to cook a pre-determined dinner, shop for those ingredients and cook the meal. In an effectual way, however, in which the meal is not pre-determined, the chef would cook a meal, among many possible meals, based on the existing ingredients and utensils in the kitchen. In this case, the selection of the menu would solely depend on what is available to the chef at the moment of preparation (Sarasvathy, 2001a). She also adds that the end goal or ‘an abstract human aspiration’, is the same for both approaches, but what distinguishes them is “the set of choices: choosing between means to create a particular effect versus choosing between many possible effects using a particular set of means”. Table 3.2 provides an overview of differences between causal and effectual processes.

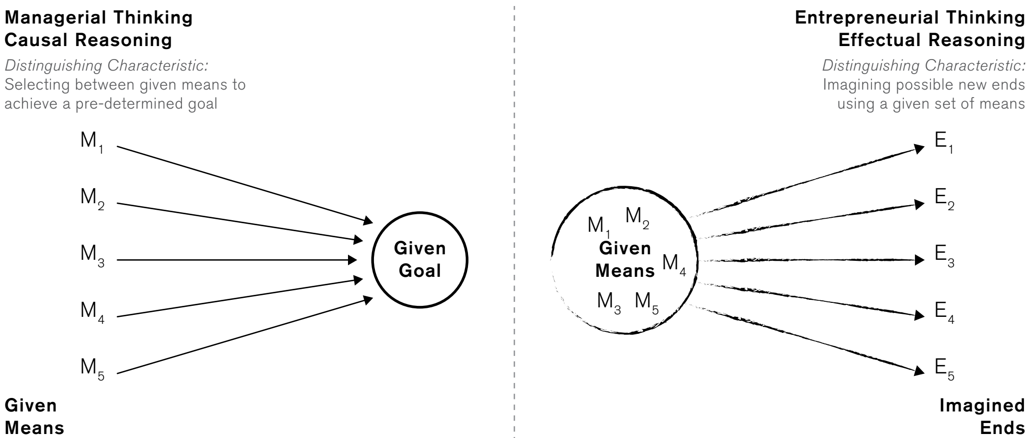


Figure 3.3. Causal versus effectual reasoning (Sarasvathy, 2001b)

Table 3.2. Differences between causation and effectuation (Adapted from Sarasvathy & Dew, 2005)

Categories of differentiation	Causation Processes	Effectuation Processes
View of the future	*Prediction.* The future is a continuation of the past; can be acceptably predicted	*Design*. The future is contingent on actions by willful agents
Givens	*Goals* are given	*Means* (Who I am, what I know, and whom I know) are given
Decision agenda	*Resources.* What resources ought I to accumulate to achieve these goals?	*Effects*. What effects can I create with the means I have?
Basis for taking action	*Desired worlds.* Vision of a desired world determines goals; goals determine sub-goals, commitments, and actions	*Possible worlds*. Means and stakeholder commitments determine possible sub-goals— goals emerge through aggregation of sub-goals
Basis for commitment	*Should.* Do what you ought to do—based on analysis and maximization	*Can.* Do what you are able to do—based on imagination and satisficing
Stakeholder acquisition	*Instrumental view of stakeholders.* Project objectives determine who comes on board	*Instrumental view of objectives.* Who comes on board determines project objectives
Predisposition toward risk	*Expected return.* Calculate upside potential and pursue (risk adjusted) best opportunity	*Affordable loss.* Calculate downside potential and risk no more than you can afford to lose
Predisposition toward contingencies	*Avoid.* Surprises may be unpleasant. So invest in techniques to avoid or neutralize them	*Leverage*. Surprises can be positive. So invest in techniques that are open to them and leverage them into new opportunities
Attitude toward others	*Competition.* Constrain task relationships with customers and suppliers to what is necessary	*Partnership.* Build your market together with customers, suppliers and even prospective competitor
Underlying logic	*To the extent we can predict the future, we can control it*	*To the extent we can control the future, we do not need to predict it*

3.3.2. Principles of effectuation

Effectual logic differs from causal logic in terms of four main principles: the-bird-in-hand, the affordable-loss, the crazy-quilt and the lemonade principle that are considered to explain the decision making logic of entrepreneurs in terms of basis for action, the approach to investment, attitude towards other actors and the attitude towards contingencies, respectively (Dew, Read, Sarasvathy, & Wiltbank, 2009).

Bird-in-hand principle. Causal logic is goal driven, i.e. means are selected in order to achieve a given goal. In contrast, effectual logic does not begin with a pre-defined goal. Goals emerge from a given set of means; therefore, the basis for action for effectual logic is the means under the control of the entrepreneurs. Sarasvathy (2001a) distinguishes means at three levels: the individual entrepreneur, firm and socio-economical levels. The means at an individual level depend on who the entrepreneur is, what he/she knows and whom he/she knows, i.e. "their own traits, tastes, and abilities; the knowledge corridors they are in; and the social networks they are a part of". The firm level resources include physical, human, and organizational resources and the socio-economical level includes demographics, current technology regimes, and sociopolitical institutions (Sarasvathy, 2001a).

Affordable-loss principle. While in causal logic, investments are typically done based on 'the prediction of possible gains' for a number of alternative scenarios, in an effectual logic they are made based on what entrepreneurs can afford to loose (Sarasvathy, Kumar, York, & Bhagavatula, 2014). The affordable loss principle eliminates the dependence of the entrepreneur on predictions of future sales, possible risks and market conditions, which are often difficult to calculate. Affordable loss is very personal and it depends on who the entrepreneur is, i.e. "his or her current financial condition and a psychological estimate of his or her commitment in terms of the worst-case scenario" (Sarasvathy, 2008). Because it is non-predictive, affordable loss eliminates the challenge of making predictions and calculations about the future. By applying the principle of affordable loss, entrepreneurs experiment with a number of strategic options "that create more options in the future over those that maximize returns in the present" (Sarasvathy, 2001a).

Crazy-quilt principle. The crazy-quilt principle explains the approach of entrepreneurs towards other actors. While causal logic emphasizes competition, and as a result competitive analysis for reducing uncertainty, effectual logic highlights the importance of partnership and commitments of stakeholders in eliminating uncertainty. As Sarasvathy (2008) states: "Effectuators do not choose stakeholders on the basis of preselected ventures or venture goals; instead, they allow stakeholders who make actual commitments to participate actively in shaping the enterprise". This way business and product goals evolve, i.e. opportunities are created, based on the inputs of a number of 'self-selected' stakeholders.

Lemonade principle. The name of this principle is derived from the cliché: "When life gives you lemons, make lemonade" (Sarasvathy, 2008). It basically explains the attitude of entrepreneurs towards emerging contingencies during the venture development process. While the causal logic emphasizes 'avoiding the unexpected' through various modes of prediction and planning, thus 'achieving predetermined goals *in spite of* contingencies', the effectual logic embraces the unexpected and strives to 'exploit those contingencies' (Sarasvathy, 2008, emphasis in the original). Therefore, for an effectuator, uncertainty is not something to avoid but rather a resource utilized in creative process of venture development.

3.3.3. Process dynamics of causation and effectuation

The predictive rationality of casual reasoning defines a process, in which opportunities are identified at the beginning of the process. These are then followed by a number of linear steps such as market research, competitive analysis, development of a business plan, acquisition of resources to implement the business plan and adopting it based on feedback from the emerging environment (Read, Dew, Sarasvathy, Song, & Wiltbank, 2009). The causal process is illustrated in Figure 3.4. In a causal approach, considerable amounts of time and resources are spent on activities such as research and analyses, in an effort to achieve a predetermined market or product idea from an optimal market segment (Sarasvathy, 2008).

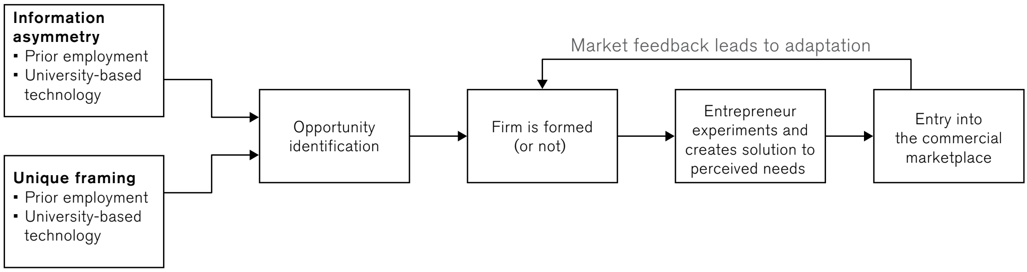


Figure 3.4. Linear activities in a causal process (adapted from Shah and Tripsas 2007)

Therefore, the causal process of, for instance, developing an imaginary restaurant would be in the following fashion: conducting market research into the restaurant industry in a specific neighborhood or city, selecting a location based on market research, identifying a market segment based on interviews, focus groups and the estimates of potential return, designing a restaurant in order to appeal that market segment, raising the required funding, bringing the team together and finally implementing specific market strategies and managing daily operations in order to make the restaurant a success (Sarasvathy, 2008).

In contrast, an effectual process starts with a set of means available to the entrepreneurs (bird-in-hand principle). Pragmatically, entrepreneurs start thinking of what they *can* do with their given sets of means rather than what they *should* do (affordable loss principle). They begin to imagine and implement possible effects that can be created and are worth creating (Sarasvathy ,2001). They move directly into action and interaction with other people (crazy quilt principle). Those who commit to the new venture bring in new means and goals. This results in an expanding cycle of means and a converging cycle of goals. Through the process of converging cycles of goals, new markets are co-created through stakeholder commitments (Sarasvathy, 2008). Figure 3.5 depicts the dynamics of the effectual process, integrating the principles of effectuation.

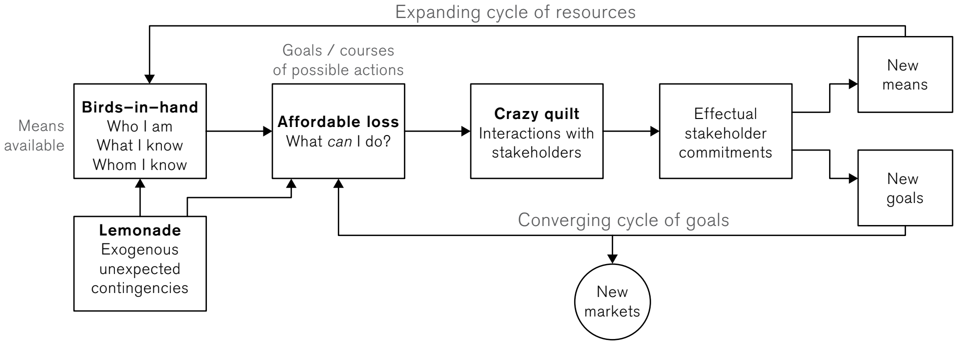


Figure 3.5. Dynamics of an effectual process (adapted from Sarasvathy et al., 2014)

In an effectual way, the restaurant example would follow a different path depending on who the entrepreneur is. Instead of starting with a predetermined market segment and investing resources for research and design, the entrepreneur could take a number of possible actions with low levels of investment. Supposing the chef is a female Indian cook, she could partner with an existing restaurant, participate in food fairs or start a catering service. If she could also convince some of her friends to use the catering service for lunch at their office, and people show interest, this could be a way to generate some capital to start a restaurant. Equally, it is possible that the lunch service does not take off; however, during her interactions with people, she discovers that customers are interested in her ethnic background and life philosophy. This could lead her to another possible end which was not imagined at the beginning of the process such as filming cooking videos, writing a book or offering motivational consultancy (Sarasvathy, 2008).

Within this conceptualization of new market creation, components of a market include demand and supply side elements, as well as institutional structures such as needs and wants; technologies, products and services; and channels and regulatory systems. Each actor committing to the venture negotiates a part of the emerging market in a patchwork fashion. As a result, "As the effectual network grows over time and includes more and more of the external world, it tends to become less effectual as it eventually coalesces into an empirically distinct new market" (Sarasvathy, 2008).

Although Sarasvathy (2008) theoretically uses the causal and effectual dichotomy, she acknowledges that entrepreneurs use both approaches in varying degrees, depending on their level of entrepreneurial expertise and life cycle of their firms. Firstly, a firm is conceptualized as 'an instrument of learning' for an entrepreneur. Entrepreneurs learn from firm failure and success, and as result, increase the likelihood of success over their career. Thus, the chance of success of a particular firm is positively correlated with the level of expertise of an entrepreneur. Furthermore, effectuation has a traits aspect as well. In other words, independent from the level of expertise, some entrepreneurs might be better at using effectual logic “due either to innate traits and tendencies or to previous life experiences that may or may not include an entrepreneurial component” (Sarasvathy, 2008). Furthermore, the availability of resources has a moderating effect on entrepreneurs’ use of causal and effectual logic:

> “In general, when entrepreneurs have few resources, they are forced to use effectual approaches, whether they prefer to or not – necessity being the mother of zero resources-to-market, so to speak. But as their entrepreneurial expertise grows, one would expect them to become more discerning in their use of appropriate logics for any given situation. Once they become entrenched experts, however, and have a more sophisticated understanding of effectual actions and the world entailed by those actions, they consciously prefer an effectual logic.” (Sarasvathy, 2008).

Secondly, considering the temporal dynamics of the venture development process, it is argued that the use of effectual logic might be higher in the early phases of a venture due to higher levels of uncertainty (Reymen et al., 2015; Sarasvathy, 2008). As firms survive and grow, the structure of the new product and market becomes solidified and visible, leaving no room for negotiating the emerging opportunity (Wiltbank et al., 2006). This might require the use of a more causal logic, which is necessary for exploitative activities. However, Sarasvathy (2008) argues that most expert entrepreneurs fail to converge into a causal logic; either because they do not prefer, or are incapable of doing so. As a result, the firms they create are usually run by others in the latter phases of the process. These arguments are depicted in Figure 3.6.

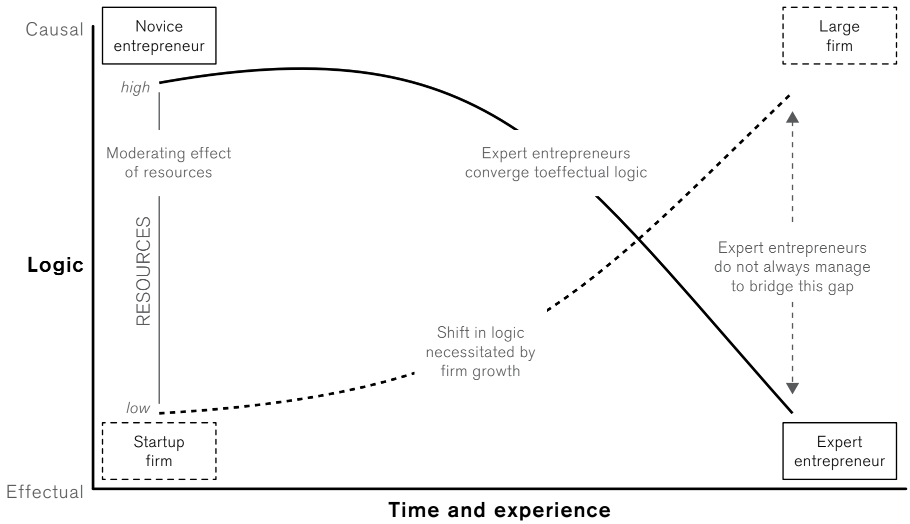


Figure 3.6. The dynamic use of causal and effectual logic based on entrepreneurial expertise and life cycle of the firm (Sarasvathy, 2008)

In addition, a situation is not uncertain as such, and how entrepreneurs experience and perceive uncertainty is an important factor that is likely to influence the venture development process. For instance, Milliken (1987) defines uncertainty as "an individual's perceived inability to predict something accurately." The underlying beliefs of entrepreneurs about the future, i.e. whether it is measurable or true uncertainty, is likely to have an influence on their decision-making, i.e. whether they predominantly use causal or effectual logic. Consequently, the perceived uncertainty might influence the venturing process over time, and the actions undertaken by entrepreneurs.

3.3.4. Behavioral implications of effectuation versus causation

As this study builds upon the behavioral tradition of entrepreneurship, this section discusses the behavioral implications of effectuation. Bird and Schjoedt (2009) define entrepreneurial behavior as "the concrete enactment of individual or team tasks or activities required to start and grow a new organization." These activities and actions are the outcome of knowledge, abilities, cognitions and motivations of entrepreneurial individuals and teams. While cognitive processes, for instance, are invisible, behaviors are visible and observable, e.g. decision-making versus writing down the decision (Bird & Schjoedt, 2009).

Although effectuation is based on the cognitive aspects of entrepreneurship, Sarasvathy (2008) gives hints of its behavioral implications in the above restaurant example. In addition, there have been a number of recent studies that translate the principles of effectuation into the individual behavior of entrepreneurs, and develop measures to empirically observe such behaviors. For instance, building upon the paper of Sarasvathy (2001a), Chandler et al. (2011) developed a Likert-type scale, which conceptualizes the four principles of effectuation as:

1. A focus on short-term experiments to identify business opportunities in an unpredictable future (effectuation) versus prediction of an uncertain future by defining the final objective up front (causation).
2. A focus on projects where the loss in a worst-case scenario is affordable (effectuation) versus maximization of expected returns (causation).
3. An emphasis on pre-commitments and strategic alliances to control an unpredictable future (effectuation) versus business planning and competitive analyses to predict an uncertain future (causation).
4. Exploitation of environmental contingencies by remaining flexible (effectuation) versus exploitation of pre-existing capabilities and resources (causation).

In this conceptualization, experimentation, which has not been associated with new venture creation in entrepreneurship literature, is introduced as a type of behavior; hence, it is argued that effectual entrepreneurs conduct a series of short-term affordable experiments in an effort to find a viable business model. In summary, the behaviors associated with causation are as follows: analyzing and selecting opportunities based on returns, developing strategy to best take the advantage of resources and capabilities, designing and planning business strategies, implementing control process for meeting objectives, researching target markets and conducting competitive analysis, developing a clear vision, designing and planning for production and marketing and making pre-commitments in order to acquire resources to reach objectives at the outset. The behaviors associated with effectuation are categorized into four main topics: experimentation, affordable loss, flexibility and pre-commitments. Experimental actions involve trying out different products and business models, which might change over time. Affordable loss related actions involve committing resources no more than the team members and firm can afford to loose. Flexibility related actions involve allowing the business to evolve, adopting the business based on resources at hand and avoiding courses of actions that restrict flexibility and adaptability. Finally, pre-commitment related actions are making pre-commitments with stakeholders as often as possible in order to reduce uncertainty.

In a similar vein, building upon the Likert-type scale of Chandler et al. (2011), Fisher (2012) explored the behavioral implications of effectuation and causation through a case study of six emerging firms. A number of behaviors associated with causation and effectuation were identified (Table 3.3) and then matched with the case study data in order to investigate the relevance of approaches in explaining the emergence of ventures. Fisher (2012) concludes that although effectuation empirically appears to be more representative of entrepreneurs' actions in building their ventures, the data suggests that the entrepreneurs also employ behaviors associated causation. This is inline with the argument of Sarasvathy (2008): "Both causation and effectuation are integral parts of human reasoning that can occur simultaneously, overlapping and intertwining over different contexts of decisions and actions", thus research should focus on the circumstances in which entrepreneurs use these contrasting logics (Fisher, 2012).

3.3.5. Behavioral implications for the product innovation process

With products they originally intended to design and develop, new ventures often find themselves in markets other than those they initially set forward in. This study was motivated by understanding why and how this process evolves: what actions drive the evolution of product-market (PM) goals, and eventually how the product innovation process can be described in new ventures?

The behavioral implication of causation and effectuation has been discussed in the previous section. Causation and effectuation provide different explanations on how the product innovation might evolve in new ventures, and the type of actions undertaken by entrepreneurs over time. First of all, the two views fundamentally differ in terms of their assumption regarding goals. While causation suggests that goals are predefined at the outset of the process, effectuation claims that goals emerge from the process itself. Therefore, it is likely

Table 3.3. Behaviors associated with causation and effectuation (Adapted from Fisher 2012)

Decision-making logic	Behaviors
Causation	▪ Identifies an opportunity before developing anything: - Gathers information about customer needs to identify a gap - Analyzes technological trends ▪ Identifies and assesses long-run opportunities in developing the firm: - Maps out (writes up and discusses) scenarios for the firm's future - Creates and compares financial projections for firm growth ▪ Calculates the returns of various opportunities: - Conducts probability analysis to choose between various alternatives ▪ Develops a business plan: - Produces a written business plan document - Presents a business plan to external audience ▪ Organizes and implements control processes: - Establishes an internal reporting structure - Designs and implements a clear organizational structure ▪ Gathers and reviews information about market size and growth: - Gathers data about the market - Interviews potential customers ▪ Gathers information about competitors and analyzes their offerings: - Gathers data about competitors - Analyzes data about competitors - Uses data about competitors as an input into key decisions ▪ Expresses a vision and/or goals for the venture: - Articulates a vision or goal - Holds strategic sessions in which goals are discussed ▪ Develops a project plan to develop the product and/or services: - Produces a project plan - Monitors product and market development in relation to a project plan ▪ Writes up a marketing plan for taking the products/services to market: - Produces a marketing plan - Implements and monitors marketing activities in accordance with a marketing plan
Effectuation	*Experimentation* ▪ Develops multiple variations of a product or service to arrive at a commercial offering: - Creation of multiple different product prototypes - Delivering different services in the process of finding an offering ▪ Experiments with different ways to sell and/or deliver a product or service: - Use of different distribution channels - Use of different revenue models ▪ Changes the product or service substantially as the venture develops *Affordable loss* ▪ Commits only limited amounts of resources to the venture at a time: - Seeks out ways of doing things in inexpensive ways ▪ Limits the resources committed to the venture in to what could be lost: - Develops product or service using only personal resources *Flexibility* ▪ Responds to unplanned opportunities as they arise: - Rapidly changes the offering or revenue model of the venture as new opportunities arise ▪ Adapts what they are doing to the resources on hand: - Focuses on what is readily available when deciding on a course of action ▪ Avoids courses of action that restrict flexibility and adaptability: - Consciously rejects courses of action that will lock them in (relationships or investments) *Precommitments* ▪ Enters into agreements with customers, suppliers, and other organizations: - Negotiates with other parties prior to having a fully developed product or service

that entrepreneurs who predominantly use an effectual logic are more flexible with the definition of the PM pair, and respond to the feedback from stakeholders more actively. In other words, they are more likely to let the stakeholder to drive the PM goals.

Moreover, the actions associated with causation, such as market research, calculations of financial return and competitive analysis, mirrors the rational view of the product innovation process, as discussed in section 2.2. In section 2.2.2, it was concluded that small firms often do not engage in such formalized practices due to their distinct organizational characteristics. Then the question is: which actions drive the product innovation process in new ventures? Although causation and effectuation provide different explanations and propose distinct processes (Figure 3.4 and 3.5), some similarities still exist. Firstly, in both cases, feedback from stakeholders influences goals, although effectuation fundamentally puts a more important role on stakeholders. Secondly, both cases view experimentation with solutions as an important element of the process. Experimentation is particularly important for this study; since, as concluded in the previous chapter, the product innovation process in new ventures can be described as an iterative experimental process driven by a series of design experiments. Design experiments have an important role on the evolution of goals. Although experimentation is highlighted in both causation and effectuation, it appears that they have fundamentally different roles. The following paragraphs expand on this.

The management approaches as discussed in section 2.4, suggest that the experience or feedback gained in an experiment influence subsequent decisions, and enable firms to adapt their course of action to increase their chance of a desired outcome. In other words, innovation management approaches are characterized by generating variation based upon adaptation, which implies a causal process. However, Sarasvathy (2008) states that the innovation process involves generating alternatives not only through adaptation, but also through a phenomenon called 'exaptation'. According to Mokyr (2000, p. 57): "The basic idea is that a technique that was originally selected for one trait owes its later success and survival to another trait which it happens to possess." Accordingly, exaptation creates a different type of variation than adaptation. As an example, Sarasvathy (2008) describes the variety of hammers that are designed for different kind of nails (i.e. finding various solutions for the same problem). Differently, exaptation is about finding solutions for various problems (i.e. finding other types of use). While adaptation is a convergent process, exaptation is a divergent process. It generates new possibilities: "It transforms resources by converting them from established uses (things they were designed for) to new uses (things they weren't designed for)" (Sarasvathy, 2008). For instance, entrepreneurs can deploy exaptation by not only asking 'what can I do?' with a set of available means, but also 'what else can I do?' with them. The question of 'what else?' generates different types of variation in comparison to adaptation. Sarasvathy (2008) claims that the basic premise of effectuation, i.e. generating new possibilities through available means and stakeholder commitments, implies that effectuation is explicitly exaptive. This gives rise to the following question of which the answer appears to be true: Can the underlying logic of experimentation in effectual processes be exaptation?

Referring to the example of the imaginary Indian restaurant from a product innovation perspective, exaptation emerging from stakeholder interactions and design experiments could be illustrated as follows. During the entrepreneur's interactions in cooking classes, some customers had shown interest in her traditional Indian wood stove she used during cooking; however, this may not fit their kitchen, culture or design taste. Such a situation may give rise to a number of ideas; for instance an electronic stove with different aesthetics, dimensions and features such as different Indian menu options to cook dosa, chapati, curry and idli; or a compact modern looking wood stove which creates no smoke to prevent the kitchen from dirt and smell. If the idea to develop the modern wood stove idea was taken further, she might start designing and prototyping to develop and achieve an almost smokeless stove. During this process however, it might be discovered that the stove creates a lot of heat as a side effect of the efficient and smokeless incineration technology, making it unsuitable and unsafe for indoor use. This might force her to optimize or redesign her current product concept, develop a different application to appeal to the target segment, or imagine alternative segments with similar demands and requirements that her current product concept would fit with small optimizations or a complete redesign. For instance, she might decide to switch to gas as the energy source for the stove, giving up the wood flavor. Alternatively, she might start to think about alternative uses of the compact smokeless wood stove, and eventually conclude that the stove is also suitable for outdoor use such as for picnics and camping, i.e. shifting to other markets. In this way, robustness as a requirement might become an important aspect in the design of the stove. As a result, besides stakeholder interactions, the very act of design and embodiment has a significant influence on PM goals. Therefore, both design experiments and stakeholder interactions can be adaptive and exaptive in nature*.

A synthesis of these ideas suggests that if the product innovation process is driven by design experiments and stakeholder interactions, as proposed in this study, entrepreneurs that predominantly use causal logic are likely to engage in experiments and interactions more adaptive in nature, with a focus on converging goals. Entrepreneurs that predominantly use effectual logic are likely to engage in experiments and interaction that are more exaptive in nature, with a focus on generating new possibilities.

** In fact, and not surprisingly, exaptation resonates well with the design discipline whose essence is creativity and generating alternatives. However, the majority of design process models suggest a linear process of information gathering, analysis, synthesis, planning and implementation, which reflect a causal approach. Idea generation is an activity that is based upon systematic information gathering through approaches such as 'contextmapping', focus groups, interviews and others (see Delft Design Guide for a comprehensive list of tools and methods); and precedes the embodiment of product ideas or experimenting with physical applications. Although creative action-based perspectives are emerging, such as 'design thinking' and 'context variation by design' (Kersten, Crul, Diehl, & Van Engelen, 2015), which highlights the discursiveness of the design process, and creates variations not only in products but also markets and networks, they are still in their infancy and lack empirical ground. Not surprisingly, the notion of 'design thinking' can be traced back to Herbert A. Simon (1969).*

3.4. CONCLUSIONS

This chapter has reviewed the entrepreneurship literature in order to address the following research questions:

- What actions drive the innovation process in new ventures, in particular the definition of product-market combinations? (RQ 1b)
- What factors influence the product innovation in new ventures? (RQ 2a)

RQ 1a has been partly answered in Chapter 2, which concluded that experimentation is a crucial action that drives the evolution of PM goals in new ventures. This chapter reviewed the entrepreneurship literature in order to identify other types of actions that are likely to drive the product market goals in entrepreneurial settings. For this purpose, the opportunity identification literature is reviewed, and the implications of discovery and creation view of opportunity identification are discussed with a focus on the causation-effectuation dichotomy. Although the two views fundamentally differ in their assumptions on goals, i.e. whether they are predefined or emerge along the process, and the type of actions entrepreneurs undertake along the process, the feedback from stakeholders and experimenting with solutions are actions that are common to both causal and effectual processes. Although the timing, driver and the impact of these actions are likely to vary in causal and effectual process, design experiments and stakeholder interactions have been selected among the actions as key constructs because they are likely to influence PM goals. Therefore, new ventures progressively define their PM pair by experimenting with PM ideas and interacting with stakeholders.

Furthermore, another objective of this chapter was to identify factors that are likely to explain the evolution of product innovation process in new ventures. The causation-effectuation dichotomy provides a suitable lens to study the similarities and differences among the new ventures' product innovation process. Firstly, it offers explanations on why and how entrepreneurs use causal and effectual logics during the venture development process. In this regard, entrepreneurial expertise and availability of resources has been selected among the determinants as key factors; they are likely to influence the type of logic and consequently the behaviors of the entrepreneurs, i.e. flexibility of entrepreneurs with PM definitions, as well as the driver, timing and frequency of design experiments and stakeholder interactions. Secondly, effectuation provides a process perspective on the dynamics of causation-effectuation over time. Considering the temporal dynamics of the venture development process, the use of effectual logic is likely be higher during the early phases of the innovation process due to the higher levels of uncertainty. However, a situation is not uncertain *per se*, implying that it is crucial to understand how entrepreneurs experience and perceive uncertainty. Entrepreneurs' perception of uncertainty is therefore, likely to influence their preference to use effectual and causal logic.

As a result, the following factors are expected to influence the process:

- Entrepreneurial expertise: the number of previous ventures founded.
- The resource position of the firms: the level of financial resources necessary for engaging in design experiments.
- The level of entrepreneurs' perceived uncertainty: entrepreneurs' perception of technical feasibility and market viability.

This study expects to find that differences among these factors are likely to result in different patterns of product innovation processes among new ventures.

Chapter 4

Sustainable Entrepreneurship

Within the last two decades, entrepreneurs motivated by goals other than maximizing economical gains have been attracting growing academic interests among entrepreneurship scholars. The expansion of entrepreneurship from ‘equating individual motivations to financial goals’ to ‘creating social and environmental value’ has brought back Schumpeter’s ‘innovative entrepreneur’ into the debate concerning sustainability and entrepreneurship. When viewed in this way, the motivations of entrepreneurs have important implications for how they engage in the entrepreneurial process. Therefore, the purpose of this chapter is to address the following questions:

- How does sustainability motivation vary among entrepreneurs? (RQ 3a)
- How does sustainability motivation influence the decision-making process, in particular the definition of product-market combinations? (RQ 3b)

This chapter initially provides an overview of the literature in the nascent fields of social, environmental and sustainable entrepreneurship, and presents a comparison across these fields (4.1). Subsequently, the small but growing research on individual motivations and their influence on the entrepreneurial process are discussed (4.2).

4.1. SUSTAINABLE ENTREPRENEURSHIP: AN EXPANDED VIEW OF VALUE CREATION

With the influence of strategic management research, scholars in entrepreneurship traditionally link entrepreneurial success to financial performance or firm survival. Recent insights suggest that there are other types of entrepreneurs, such as lifestyle entrepreneurs or craftsmen, that are motivated by goals other than maximizing economic gains (Carsrud & Brännback, 2011). Moreover, scholars have been criticizing the mainstream entrepreneurship research for focusing on the economic function as the only criterion for venture performance, and calling for the reinterpretation of the field of entrepreneurship in ways that address social and ecological challenges linked to human well-being. Viewed in this way, the notion of entrepreneurship expands from equating individual motivations to desire for profit to “designing the society we want to live in” (Sarasvathy, 2004), as well as creating social and environmental value (Cohen, Smith, & Mitchell, 2008).

The literature at the intersection of sustainability and entrepreneurship can be categorized into social, environmental and sustainability entrepreneurship; based upon the type of societal issues entrepreneurship aims to address. In the following paragraphs, social and environmental entrepreneurship as the precursors of sustainability entrepreneurship are reviewed, including a number of definitions and typologies. Subsequent to this, the nascent field of sustainable entrepreneurship is reviewed.

4.1.1. Social entrepreneurship

Social entrepreneurship, as a field of research, emerged in the late '90s, and has rapidly flourished in academia, business education and popular press (Peredo & McLean, 2006). Although there is little consensus on what social entrepreneurship actually is, Mair and Martí (2006) distinguishes between three groups of interpretations: (1) nonprofit activities that use business principles in creating social value, (2) socially responsible commercial ventures, and (3) innovative efforts in creating solutions to social problems and transforming social systems. The first group of interpretations has received by far the most scholarly interest due to its roots of social entrepreneurship in the non-profit sector. The majority of scholars have emphasized the social mission and non-profit activities as a distinctive feature of social entrepreneurship. Accordingly, for social entrepreneurs, financial outcomes are just a means to ends, i.e. the social mission (Dees, 1998). The second group of interpretations reflects the growing interest in social-purpose commercial ventures. Some scholars have argued that the main focus on social goals should neither limit social entrepreneurs to only social wealth creation, nor prevent them from pursuing financial goals (Mair & Martí, 2006). Similarly, Chell (2007) argues that the notion of social entrepreneurship should move beyond the nonprofit charitable organizations, and be applied to both social and entrepreneurial ventures that create both social and economical value. As such, she defines social entrepreneurship as a process of "recognizing and pursuing opportunities with regard to the alienable and inalienable resources currently controlled with a view to value creation". In this view, social enterprises, just like commercial enterprises, should be self-sustaining and entrepreneurial for the sustainability of their ventures (Chell, 2007). In an effort to integrate the non-profit and for-profit perspectives, Paredo and McLean (2006) argue that the debate about degree of priority of social goals has little practical value and pursuing a social goal should qualify as social entrepreneurship; so as to distinguish social entrepreneurs from conventional ones. They suggest viewing social and economic goals as a continuum that results in a range of organizations. On one extreme are the non-profits who are exclusively driven by social goals and view profit as instrumental. On the other extreme are the commercial organizations who are chiefly driven by social goals and aim to create profit for themselves and others. Viewing social entrepreneurship as a way to bring about social transformations, scholars in the third cluster conceptualize social entrepreneurship as an innovative phenomenon (Alvord, Brown, & Letts, 2004). In this regard, Austin, Stevenson, and Wei-Skillern (2006) define social entrepreneurship as "innovative, social value creating activity that can occur within or across the nonprofit, business, or government sectors." Mair and Marti (2006) define social entrepreneurship as "a process involving the innovative use and combination of resources to pursue opportunities to catalyze social change and/or address social needs."

Despite the different perspectives and conceptualizations of social entrepreneurship, scholars appear to agree that the most distinguishing characteristic of social entrepreneurship is its social mission and consequently the social value creation.

4.1.2. Environmental entrepreneurship

While much of the extant literature on environmental concerns and business have addressed small and medium sized enterprises and how to 'green' their practices (Walley & Taylor, 2002), the scholarly interest in environmental entrepreneurship, also often called as ecopreneurship (Schaltegger, 2002; Schaper, 2002), enviropreneurship (Menon & Menon, 1997) or green entrepreneurship (Walley & Taylor, 2002), has been growing since late '90s with more focus on innovative new ventures (Parrish, 2007). In that respect, a majority of scholars have highlighted the role of environmental entrepreneurs in transforming the economy and society towards environmentally responsible practices.

Different to the arguments in social entrepreneurship, which emphasize social mission over economic goals, scholars appear to broadly agree that environmental entrepreneurship is the pursuit of profitable opportunities that create environmental value. For instance, Schaltegger (2002) suggests, "ecopreneurs differ from conventional entrepreneurs in that they also build bridges between environmental process and market success." One of the key articles in the field of environmental entrepreneurship is Dean and McMullen's (2007) work that draws on environmental and welfare economics. According to Dean and McMullen (2007), environmentally relevant market failures associated with the neoclassical economics assumptions of perfect markets, present abundant opportunities for entrepreneurs. As such, the authors define environmental entrepreneurship as "the process of discovering, evaluating, and exploiting economic opportunities that are present in environmentally relevant market failures". These market failures involve inefficient firms, negative externalities, imperfect pricing, monopoly power and inappropriate government intervention. Dean and McMullen (2007) claim that entrepreneurial action can increase the efficient use of natural resources by addressing these market failures. From this perspective, those entrepreneurs who are alert to such market failures can simultaneously gain personal profits and improve the efficiency of the market and the ecology. York and Venkataraman (2010) adapt a broader perspective on the role of entrepreneurial action in addressing environmental degradation through innovation. These authors suggest that the act of entrepreneuring involves not only discovering and evaluating opportunities, but also creating new opportunities and possibilities (Sarasvathy & Venkataraman, 2009; York & Venkataraman, 2010). Therefore, while clearly defined issues can be address by regulation, issues such as climate change involve high levels of uncertainty, and as such, can be addressed by innovation. This interpretation suggests that entrepreneurs are potential candidates for the creation of alternative solutions because they are driven by uncertainty (York & Venkatraman, 2010).

Similar to social entrepreneurs, environmental entrepreneurs are driven by goals other than profit maximizing. Environmental entrepreneurs evaluate opportunities based upon their mission (Dixon & Clifford, 2007), environmental commitment (Keogh & Polonsky, 1998) and ethical reasoning (Linnanen, 2002). The main difference however, is that economical value creation is as important as environmental value creation. Therefore, the field of environmental entrepreneurship focuses mainly on for-profit ventures.

4.1.3. Sustainable entrepreneurship

Sustainable entrepreneurship originates from the concepts of 'sustainable development' and 'triple bottom line' thinking as put forward in the Brundtland report (WCED, 1987) and by Elkington (1998), respectively. Accordingly, a majority of definitions stress the integration of all three dimensions of sustainability in distinguishing sustainable entrepreneurship from other forms (see Table 4.1). For instance, Young and Tilley (2006) argue that sustainable entrepreneurship is "the incorporation of all elements of sustainable development, not just some". Schlange (2006, p. 18) suggests that sustainable entrepreneurship is a "distinct approach to balance the requirements of the triple bottom line". N. Thompson et al. (2011, p. 214) state sustainable entrepreneurship "focuses on entrepreneurial action that seeks to achieve simultaneous (1) social benefits, (2) economically viable organizations, and (3) reduction of environmental degradation." They suggest that what distinguishes sustainable entrepreneurship from others is "the long-term benefits across triple bottom line perspectives". In that respect, Cohen et al. (2008) propose that the motivation of entrepreneurs influence their value creation strategies, and as a result, how they evaluate the outcome of these strategies. Accordingly, they suggest a typology of entrepreneurial value creation based on the triple bottom line of sustainability. The typology consists of seven domains of value creation: economic performance (achievement of economic objectives), promise (achievement of social objectives) and perpetuity (achievement of environmental objectives), socio-efficiency (achievement of socio-economic objectives), stewardship (achievement of socio-environmental objectives), eco-efficiency (achievement of enviro-economic objectives) and sustainability (achievement of socio-enviro-economic objectives) (Cohen et al., 2008).

Table 4.1. Differences between social, environmental and sustainable entrepreneurship (adapted from-Schaltegger & Wagner, 2011)

	Social entrepreneurship	Environmental entrepreneurship	Sustainable entrepreneurship
Core motivation	Contribute to solving societal problem and create value for society	Contribute to solving environmental problem and create economic value	Contribute to solving societal and environmental problems through the realization of a successful business
Main goal	Achieve societal goal and secure funding to achieve this	Earn money by solving environmental problems	Creating sustainable development through entrepreneurial corporate activities
Role of economic goals	Means	Ends	Means and ends
Role of non-market goals	Societal goals as ends	Environmental issues as integrated core element	Core element of integrated end to contribute to sustain-able development
Organizational development challenge	From focus on societal issues to integrating economic issues	From focus on environmental issues to integrating economic issues	From small contribution to large contribution to sustainable development

In solving social and ecological challenges, some scholars stress the notion of Schumpeter's 'creative destruction' and the role of sustainable entrepreneurs in developing innovations for sustainability. For example, Hockerts (2003, p. 50) argues that sustainable entrepreneurship entails "the identification of a sustainability innovation and its implementation either through the foundation of a start-up or the radical reorientation of an existing organization's business model so as to achieve the underlying ecological or social objectives." Cohen and Winn (2007) suggest that sustainable entrepreneurship can address environmental and social challenges by introducing innovations that emerge from market imperfections. Schaltegger and Wagner (2011) claim that the essence of sustainable entrepreneurship is "the realization of sustainability innovations aimed at the mass market and providing benefit to the larger part of society." In this regard, the authors propose a typology of sustainable entrepreneurs based on their ambitions to transform an industry and market, and the priority of sustainability issues as business goals (Figure 4.1). According to this typology, sustainable entrepreneurship has the highest potential to influence the society as a whole because entrepreneurs in this category aim to introduce innovations for the mass market. Whereas ecopreneurs, or environmental entrepreneurs, are less concerned with sustainability as a whole and are more focused on large market shares and turnover, as well as environmental value creation. Finally, the impact of social entrepreneurship is restricted to social groups and niche markets, and can be increased by involving economical aspects and addressing the larger parts of the society (Schaltegger & Wagner, 2011).

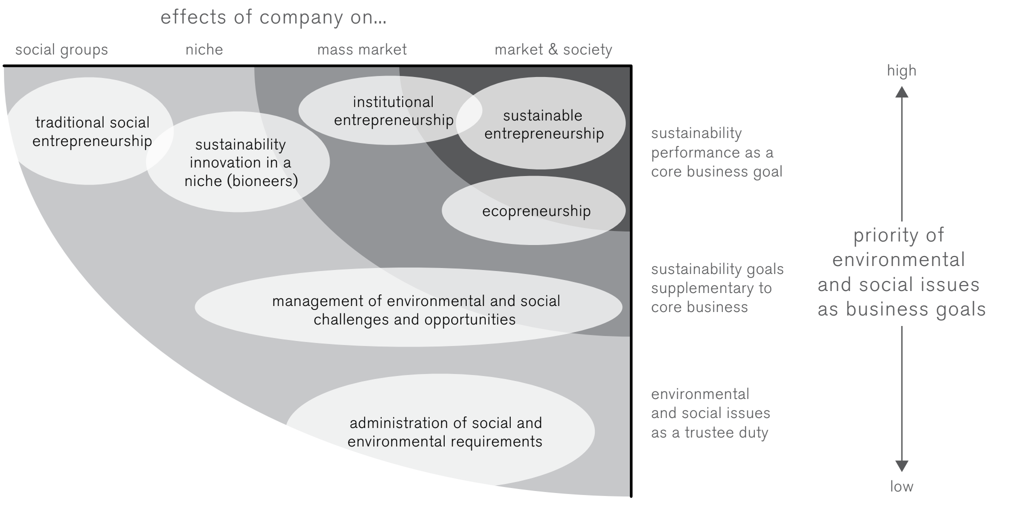


Figure 4.1. Relationship between sustainable entrepreneurship and sustainability innovation (adapted from Schaltegger & Wagner, 2011)

In conclusion, while social entrepreneurship is mainly associated with non-profit activities that have a social mission, environmental entrepreneurship puts emphasis on profitable opportunities that create environmental value, and sustainability entrepreneurship integrates all three elements of sustainability. Whether the focus is given on social and/or environmental goals; or whether the relative importance of social or environmental goals is equal or outweighs economical goals, the scholarly interest in social, environmental and sustainable entrepreneurship implies both "an expanded view of entrepreneurship beyond firm performance" and "a broader concept of value creation" (Cohen et al., 2006).

Accordingly, in this study sustainable entrepreneurship is viewed as 'individual or simultaneous pursuit of social and environmental goals in addition to economical goals'. Hence, the focus here is on for-profit ventures pursuing multiple bottom line objectives; be it two or three. The rational behind this is that it might be difficult to distinguish between social and environmental goals, and as Walley and Taylor (2002) state: "Green and ethical entrepreneurs may well have mixed motivations; their motives may not be solely green but be a combination of green, ethical and social motives, and it is often difficult to separate these (as, indeed, the concept of sustainability reflects)." Furthermore, it is assumed that pursuing multiple goals (whether social and/or environmental) is likely to influence the product innovation process in a similar manner.

Consequently, sustainable entrepreneurship is defined as 'a process of opportunity identification, in which entrepreneurs translate their initial intentions, prior knowledge and social and/or environmental motivations into new organizations through their actions and interactions with others'. In that respect, it is crucial to understand the drivers and motivations of entrepreneurs in starting and managing their businesses. The motivation construct is particularly important in this study as the interest here is on firm-level decisions.

4.2. WHAT DRIVES SUSTAINABLE ENTREPRENEURS?

The section above has briefly addressed the literature in social, environmental and sustainable entrepreneurship, in order to position the present study within the context of previous studies. This section reviews the literature with a focus on the motivations of sustainable entrepreneurs, as this has been identified as an important factor that distinguishes them from their commercial counterparts. In addition, the notion of sustainable entrepreneurship as a process of 'creative destruction' suggests that sustainable entrepreneurs' motivation to change the world and their beliefs and perceptions about the social and environmental issues, how severe they are, and whether they require radical action have important implications for how they engage in the entrepreneurial process (Beveridge & Guy, 2005), in particular, due to the inevitable tradeoffs in their decision making process. This section reviews the various typologies of sustainable entrepreneurs on the basis of their motivations. Subsequently, the implications of the motivations for the entrepreneurial process are discussed.

4.2.1. Typologies of sustainable entrepreneurs

According to Isaak (2002), there are two varieties of environmentally responsible businesses: 'green businesses' and 'green-green businesses'. A green business might not necessarily start with an environmental mission; however, it might choose to go green due to the cost and marketing advantages of greening. On the other hand, a green-green business, or the 'ideal type', is designed to be green at the outset of the business development process, and has the mission to create environmental value for the industry and society. Although Isaak (2002) acknowledges that a perfect example of a green-green businesses in practice does not exist, he adds that "to become an ecopreneur is an existentialist commitment in which the entrepreneur knows he or she will never reach the ideal; but that very ideal of sustainability gives meaning to everything the ecopreneur does on the Earth". Similarly, Linnanen (2002) suggests that what distinguishes environmental entrepreneurs from ordinary entrepreneurs is their 'ethical reasoning' or 'value-based leadership'. He suggests four distinct types of environmental entrepreneurs (as illustrated in Figure 4.2) based on their desire to change the world and desire to make profit. According to Linnanen (2002), successful idealists who have a high level of desire to change the world find themselves in a virtuous cycle of motivation to create markets, positive feedback from stakeholders, business growth and desire to change the world.

Adopting Isaak's definitions of 'green-green business', Walley and Taylor (2002) define green entrepreneurs as "socially and ethically motivated entrepreneurs who also have financial objectives". This definition treats green, ethical and social motives holistically under the label 'sustainability orientation'. Applying the structure-action framework of Giddens (1984) on environmental initiatives, Walley and Taylor (2002) also include external influences on the emergence of green entrepreneurs. They state that, "The most relevant explanatory variables for characterizing different types of green entrepreneurs are the external context (structural influences) and the entrepreneur's personal orientation or motivation." Accordingly, they have developed a typology based on two dimensions; describing an entrepreneur's motivation from economically oriented to sustainability oriented, and the influence of external context from 'soft structures (e.g. personal networks and education, past experiences)' to 'hard structures (e.g. economic incentives, customers)' (Walley & Taylor, 2002). The combination of these two dimensions results in four ideal types of green entrepreneurs (as illustrated in Figure 4.3). An 'ad hoc enviropreneur' is an accidental green entrepreneur whose primary motivation is to create financial gains, and is mainly influenced by soft structures in developing business ideas. An 'ethical maverick' is similarly influenced by soft structures such as friends and family; however, he/she is a person primarily driven by his/her values in relation to sustainability. Ethical mavericks usually operate in small niches rather than establishing mainstream organizations. An 'innovative opportunist' is viewed as the closest to a conventional entrepreneur; however, they differ in the sense that they focus on green niches or opportunities. They are influenced by hard structures such as government regulations in spotting such opportunities, for instance, by adopting new technologies. Finally, a 'visionary champion', similar to Isaak's (2002) green-green businesses, is the most pleasant type of green entrepreneur, who is primarily influenced by hard structures and value-driven motivations. Visionary champions strive to change the world and act based on their vision of a sustainable future. This is, in some manner, similar to Schaltegger and Wagner's (2011) interpretation (see Figure 4.1); however, Schaltegger and Wagner give a more detailed account of how an entrepreneurs' financial goals and market ambitions translate into different types of innovations, and the varying degrees of effect entrepreneurs create (i.e. from social groups and niche markets to mass markets and society as a whole). Although these typologies are useful in identifying ideal types of green entrepreneurs, Walley and Taylor (2002) caution that they fail to address the temporal dynamics and explain the rationale behind entrepreneurs' decision-making process. In other words, as the entrepreneurs engage in the entrepreneurial process, they might transform from one ideal type to the other (Walley & Taylor, 2002).

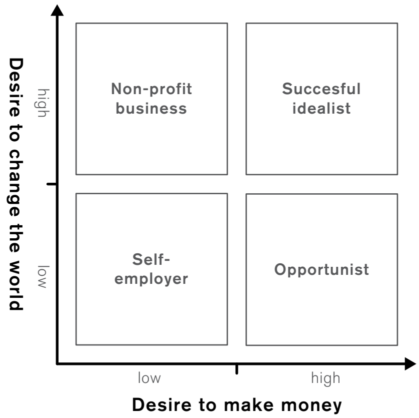


Figure 4.2. Typology of environmental entrepreneurs (adapted from Linnanen, 2002)

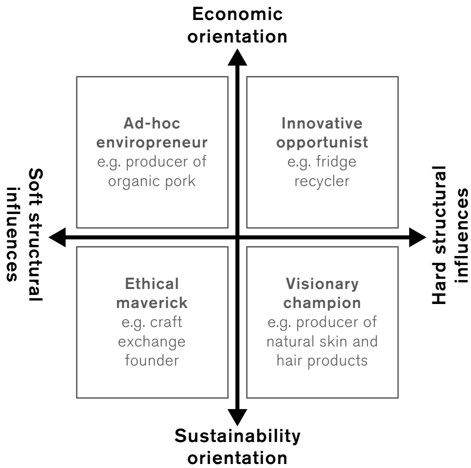


Figure 4.3. Typology of green entrepreneurs (adapted from Walley & Taylor, 2002)

Similar to Walley and Taylor (2002), Pastakia (2002) proposes a framework for ecopreneurs based on a number of internal and external drivers; however, with a focus on the context of developing countries. Internal drivers are mainly 'ideological and strategic concerns', emerge from within, and are guided by entrepreneurs' vision. External drivers, such as investors, customers, policies and regulatory context, highlight the embeddedness of entrepreneurs within the wider socio-cultural and economical system. According to Pastakia (2002), ecopreneurs emerge from the interaction of these two distinct type of drivers; however, internal drivers are key in explaining how entrepreneurs create value for society and external drivers play a role in shaping the worldview of entrepreneurs, which in turn translates into an internal force and future action. Similarly, Patzelt and Shepherd (2011) argue that entrepreneurs' motivation is the key factor in explaining how and why sustainable entrepreneurs recognize opportunities in relation to sustainable development. They suggest that entrepreneurs' beliefs on the existence of sustainable opportunities are shaped by their attention toward natural and/or communal environment, such as ecosystems and communities, respectively. Accordingly, entrepreneurs who possess prior knowledge of natural and communal environment, and are motivated to create value for themselves as well as others are likely to recognize sustainable opportunities. Moreover, prior entrepreneurial knowledge of markets and customer problems has a positive influence on this opportunity recognition process (Patzelt & Shepherd, 2011). Other researchers have also examined the intentions of sustainable entrepreneurs as the best predictor of future actions and behaviors. In this regard, Mair and Noboa (2006) focused on the sources of intentions at an individual level. The authors suggest that intentions to set up a social venture emerges from empathy and moral judgment, which influence the perceptions of desirability, and self-efficacy and social support, which in turn, influence the perceptions of feasibility. Despite these suggestions, the authors still acknowledge that we know little about how entrepreneurs' intentions translate into actual behavior, or how intentions influence the opportunity identification process.

In addition to the conceptual efforts, there are a handful of empirical studies that have looked into individual motivations. For instance, Schlange (2007) argues that if environmental entrepreneurship can be viewed as a sub-category of conventional entrepreneurship, the external factors suggested by scholars do not appear to be exclusive to sustainable entrepreneurship. Accordingly, based on a case study of 10 start-ups, the author concludes that what differentiates environmental entrepreneurs from conventional entrepreneurs are the internal factors, in particular their motivation and vision. Similarly, Schick, Marxen, and Freimann (2002) have focused on the start-up processes of sustainability driven entrepreneurs. Based on interviews with entrepreneurs and business advisors who provide consultancy services to start-ups, they conclude that start-ups vary in their ecological orientation, which is measured based upon the degree of environmentally friendly practices, such as use of renewable materials, recycling of packaging, waste sorting and compliance with environmental regulations. An interesting finding of Schick et al.'s (2002) work is that the differences among entrepreneurs' ecological considerations and approaches within the same industry were as large as differences among different industries. Accordingly, they conclude that although industry is an important factor that affects the motivation of entrepreneurs, the entrepreneur him- or herself, is the most crucial factor for the integration of environmental considerations in the start-up phase. In a comparative study, Kirkwood and Walton (2010) have explored the motivational differences between ecopreneurs and commercial entrepreneurs in starting their businesses. Based on a case study of 14 ecopreneurial companies, their findings suggest that ecopreneurs are motivated by a combination of five factors including: being their own boss, a gap in the market, passion, making a living and green values. They conclude that the unique motivation of ecopreneurs is their green values.

In conclusion, a synthesis of these conceptual and empirical efforts suggests that sustainable entrepreneurs' motivation appears to vary in terms of the type of sustainability issues they aim to address, the degree of priority of sustainability goals with respect to economic goals, as well as, the degree of change they aim to bring to the society. Although these studies help in understanding the phenomenon of sustainable entrepreneurship and the role of motivations, they have also been criticized for creating a 'typology literature' (Allen & Malin, 2008), and not offering explanations for the process of ecopreneuring; in particular, how the motivations of entrepreneurs in solving social and environmental issues translate into specific actions and behaviors, and how they engage with their external context (Beveridge & Guy, 2005). In this regard, a number of scholars have recently began to explore the implications of sustainability orientation and motivation for how entrepreneurs engage with the entrepreneurial process, in particular the inevitable tradeoffs in the decision-making process.

4.2.2. Implications for the decision-making process

The motivation to solve social and environmental issues is likely to influence the entrepreneurial process and confront entrepreneurs with a series of tradeoffs between potentially conflicting goals. The small but growing literature on the decision-making process of sustainable entrepreneurs appears to offer two different perspectives on the influence of motivations.

On the one hand are scholars, who claim that social, environmental and economic goals can be balanced in a way to build economically viable businesses that simultaneously create social and environmental value. For instance, with a focus on the entrepreneurial process, Kirkwood and Walton (2014) examined the influence of pre-existing green values of entrepreneurs on the decision-making process. Based on a nationwide survey in New Zealand (with a total of 84 questionnaires returned), they found that ecopreneurs face challenges in decision-making associated with balancing environmental and financial goals. Although they were able to keep their focus on the environment, they were also realistic and considered financial aspects simultaneously. The authors conclude that the decisions concerning how to balance environmental and financial aspects depend on particular situations, without further explaining details of the situational characteristics. Dixon and Clifford (2007) examined whether and how ecopreneurs balanced financial goals with their idealistic values that motivated them to start their ventures. Based on a descriptive single case study of a nonprofit organization, the authors claim that social and environmental goals can be translated into viable businesses by being embedded within the political, social, environmental and regulatory system, as well as establishing a business model that utilizes the waste of other organizations who are keen to demonstrate and quantify corporate social responsibility (CSR) outcomes. Similarly, based on a sample of 10 successful sustainability-driven start-ups, Schlange (2007) found evidence that sustainable entrepreneurs are able to balance multiple sustainability objectives by using the concept of sustainability as a guiding principle; without necessarily emphasizing any one of the objectives. In addition, sustainable entrepreneurs' view on success appears to help them to balance the sustainability objectives. For instance, based on a longitudinal study of a green venture, Holt (2012) argues that entrepreneurs can retain their social and environmental mission over time by refusing to maximize profits. For sustainable entrepreneurs, the measurement of success is, instead, ‘enough’ profits, and the social and environmental value created through the business. In a similar vein, Parrish (2010) claims that successful sustainable entrepreneurs have a distinct ability to align sustainability objectives by strategically satisficing multiple outcomes. Strategic satisficing operates on a logic that seeks to satisfy multiple objectives by achieving a certain threshold for each objective, instead of maximizing the outcome for a single objective.

Despite the empirical evidence suggesting the possibility of aligning sustainability objectives, some scholars argue that the win-win paradigm of achieving social, environmental and economic objectives simultaneously is a rather optimistic view (Hahn, Figge, Pinkse, & Preuss, 2010). In other words, entrepreneurs are constantly confronted with tradeoffs between multiple goals, and might sacrifice one objective at the expense of the other, i.e. ‘creating a viable business’ versus ‘staying true to the ideals’ (Dixon & Clifford, 2007). This is particularly true in the case of sustainability-oriented new ventures, which are confronted with the challenge of survival while maintaining a balance between multiple objectives. Accordingly, an emphasis on the economic goals puts ventures at the risk of loosing their social and/or environmental mission over time, which is also referred to as ‘mission drift’ (Battilana & Dorado, 2010). Concerning product-market (PM) decisions, this means that a focus on or a shift to a particular product concept and/or target market for increased commercial revenues might come at the cost of loosing the social and/or environmental benefits. In other words, an innovation that is considered to have positive sustainability effects in a certain context might have negative consequences in other parts of the system, or other phases during the lifecycle of a product (Paech, 2007). New firms face decisions concerning what products to develop, and for whom. A product in one particular market might not reveal similar sustainability benefits in another market due to different requirements or use scenarios.

On the contrary, an emphasis on social and/or environmental mission might increase the complexity of the decision making process, and escalate the commitment of decision makers to particular projects, regardless if the signals say otherwise. For instance, Berchicci (2005) examined entrepreneurs’ environmental ambition, defined as “a specific intention to develop new products with lower environmental impact”. According to Berchicci (2005), environmental ambition can be conceptualized as a non-rational factor in the decision making process, and is likely to be the underlying mechanism of the escalation of commitments. In other words, a high level of environmental ambition is likely to escalate decision-makers’ commitments to particular projects because environmental ambition might provide psychological rewards and lower performance thresholds, which in turn can cause entrepreneurs to continue with the same course of action regardless of performance (Berchicci, 2005). Furthermore, Berchicci (2005) claims that environmental ambition increases the complexity of decision-making, particularly when a tradeoff has to be made between environmental and other concerns, e.g. financial and design requirements. Regarding PM goals, sustainability ambition might escalate the commitment of entrepreneurs to a particular product concept or target market depending on the motivation of entrepreneurs; whether they aim to transform a specific market or replace existing products with alternative solutions in a variety of markets.

In summary, the limited literature on decision-making of sustainable entrepreneurs offers a handful of empirical studies with different perspectives on the possibility of balancing multiple goals. Despite the differences in perspectives, scholars appear to agree that pursuing multiple objectives increases the complexity of the decision-making process, and may cause entrepreneurs to loose their initial mission over time or risk their ventures' economic viability.

4.3. CONCLUSIONS

This chapter reviewed the literature on sustainable entrepreneurship with the purpose of addressing the following questions:

- How does sustainability motivation vary among entrepreneurs? (RQ 3a)
- How does sustainability motivation influence the decision-making process, in particular the definition of product-market combinations? (RQ 3b)

In answering these questions, the literature in social, environmental and sustainable entrepreneurship has been reviewed, with a focus on the motivation of entrepreneurs in starting and managing their ventures. A synthesis of literature suggests that entrepreneurs' motivation may differ on three dimensions: (1) the type of sustainability issue they aim to address: social or environmental, or both, (2) the degree of priority of social and/or environmental goals in comparison to financial goals, and (3) the degree of change entrepreneurs aim to bring to the market and society (i.e. their market effect). In addition, the literature suggests that pursuing multiple goals; be it two or three different goals, or be it social or environmental goals, often increases the complexity of decision-making process, and might require entrepreneurs to make tradeoffs between different goals. When confronted with tradeoffs, the sustainability motivation might cause entrepreneurs to emphasize social and/or environmental goals, and may consequently escalate their commitment to particular PM combinations. Alternatively, an emphasis on economic goals might lead new ventures to loose their mission over time. Furthermore, entrepreneurs' beliefs about the severity of social and environmental issues may influence how they engage in the entrepreneurial process, and the actions entrepreneurs undertake. Additionally, literature provides limited insights into how the ambition to bring change to market and society influences the innovation process. Does a high degree of ambition to transform a particular market escalate entrepreneurs' commitment to particular PM combinations?

Furthermore, in the previous chapter, entrepreneurship was defined as 'a process of opportunity identification, in which entrepreneurs translate their initial intentions, prior knowledge and motivations into new organizations through their actions and interactions with others'.

A process perspective adds a temporal dimension and implies that goals and motivations evolve over time; however, literature on motivations are limited in identifying different types of sustainable entrepreneurs based on their motivations and treat motivations as a static variable. As some scholars suggest, external factors, particularly interactions with other actors, as well as the processes of persuasion and negotiation, affect the motivation of entrepreneurs (e.g. Walley & Taylor, 2002; Beveridge & Guy, 2005).

When entrepreneurs engage in the entrepreneurial process, not only the opportunity, i.e. definition of PM combinations, evolves, but also the entrepreneurs' motivation in relation to this definition. The feedback from design experiments and stakeholder interactions might necessitate entrepreneurs to abandon environmental or social goals, or shift from one goal to the other; or the other way around, it might require them to adapt environmental or social goals. Alternatively, the process itself might require entrepreneurs to mute these goals over a period of time, and prioritize economical goals over environmental or social goals. As Volery (2002) stresses, financial bottom line is still the most critical one. Similarly, Isaak (2002) claims that once a business is established beyond a certain size, it goes in to a 'maintenance' phase, which might distract entrepreneurs from their environmental mission. Therefore, the relative importance of social, environmental and economical goals might vary over time. This makes the debate on social or environmental goals, or both, irrelevant.

Three relevant questions are therefore: (1) How do the entrepreneurs' motivations that caused them to start a business change over time? (2) How do these evolving motivations influence the entrepreneurial process? (3) How does the degree of change entrepreneurs aim to bring to the market influence the innovation process? These issues invite further exploration into the reciprocal relationship between the motivations of entrepreneurs and the innovation process.

Chapter 5

Conceptual Framework and Research Approach

Previous chapters have presented a range of theories and concepts regarding sustainability, product innovation and entrepreneurial behavior. This overview has enabled the identification of relevant theoretical constructs, which are synthesized in the present chapter into a preliminary conceptual framework. This framework aims to describe and explain the product innovation process of new ventures that started businesses around a product idea related to sustainability.

This chapter initially defines the building blocks of this research and explains the rationale behind their selection (5.1). Taking effectuation theory as a point of departure and introducing design experiments as an important element, a descriptive model of the innovation process in new ventures (5.2) is proposed, which is used as a sensitizing framework for data collection and analysis. In section 5.3, a number of theoretical constructs are defined that are expected to explain the similar and different patterns in innovation trajectories within the case study. These are then integrated into a conceptual framework (5.4), leading to the propositions of this study (5.5). These propositions are followed by the research design (5.6), which explains the research approach of this study.

5.1. SELECTION OF THE BUILDING BLOCKS OF THE CONCEPTUAL MODEL

Selection of a set of theoretical constructs prior to case study research is useful in documenting and analyzing the phenomenon under study (Eisenhardt, 1989). The main objective of this study is to describe and explain the product innovation processes in sustainability-oriented new ventures. Therefore, the product innovation process is described as the central construct and will be further defined in the following section.

Furthermore, Chapter 3 concluded that this study would deploy the theory of effectuation as a point of departure. In this regard, a multitude of factors were discussed, which may influence the product innovation process. In this chapter, these factors are translated into 'explanatory constructs' in order to explain the differences among the firms' product innovation processes. The relationship between the explanatory constructs and the central construct is illustrated in the conceptual model and discussed through propositions.

5.1.1. Central construct: Product innovation process

In this research, the phenomenon being studied is the product innovation process in new ventures that began from a sustainable product idea. Due to the complex and uncertain nature of sustainable innovations, uncertainties linked to radical innovation, as well as the resource constraints in entrepreneurial contexts, this study expects to find that setting clear objectives at the beginning of innovation process will be difficult, i.e. what products will be offered to whom and at what price. As a result, product-market (PM) goals are expected to evolve along the process. The firms are expected to engage in a number of PM iterations before a particular promising opportunity emerges.

Chapter 2 concluded that the innovation process in new ventures follow a non-linear fashion, requiring an experimental logic. In this process, firms learn about technology and what it can deliver through a series of design experiments (i.e. technical feasibility and sustainability performance). Moreover, Chapter 3 introduced a number of concepts from entrepreneurship literature with a focus on entrepreneurial behavior and decision-making, in order to better understand how design experimentation takes place in new ventures. It was concluded that, parallel to experimentation, firms test and learn about markets during their interactions with potential customers and partners (i.e. market viability). In other words, stakeholder interactions have a significant impact on PM goals. Therefore, the innovation process in new ventures is characterized by a series of PM iterations primarily driven by two distinct activities: design experiments and stakeholder interactions. In this study, the product innovation process is described on the basis of three constructs: (1) *PM iterations*, (2) *design experiments,* and (3) *stakeholder interactions*.

PM iterations

PM iterations refer to specific PM combinations that a firm chooses to engage in over time. PM iterations are the result of decisions made by the entrepreneurial team and concern the functionality of a product and potential customers' requirements. The rationale behind the selection of this construct is two fold. First of all, new ventures often end up in markets other than those they initially identified, and with products that are different than they had initially intended to develop (Drucker, 1985). Therefore, it is assumed that PM goals evolve along the process. New ventures face decisions on which products to develop and which markets to engage in. Secondly, one of the objectives of this study is to develop insights into the role of sustainability motivation on the product innovation process. As discussed in Chapter 1 and 2, an innovation considered to have positive sustainability effects in a certain market, might have negative consequences in other markets. Therefore, sustainability-oriented new ventures are confronted with uncertainty, not only in relation to PM decisions but also the social and environmental consequences of such decisions. Therefore, PM iterations a firm engages in over time appear to be a suitable construct in order to understand how the different motivations of entrepreneurs influence the product innovation process; in particular, the decisions to shift to alternative PM combinations, which have implications for the social and environmental consequences of an innovation.

Design experiments

This study expects that firms engage in design experimentation in order to test the technical feasibility of particular product ideas, as well as generating new alternatives. By engaging in design experiments, firms learn about the limitations and opportunities in relation to specific PM ideas. Chapter 2 presented different management practices, such as trial and error, and probe and learn. In essence, what these practices point to is the difficulty of making rational decisions in an uncertain context based on only research and analysis due to the limited information they reveal. There is a need for experimentation of various forms in order to decrease the technical and/or market uncertainty, as well as the uncertainty related to sustainability performance of the innovation.

While these practices differ in the amount of learning they provide, and whether they are conducted in controlled environments or real markets, they all require the development of a prototype (i.e. embodiment of the product idea) in order to learn about the technology and markets. Moreover, entrepreneurs use these approaches in varying degrees for different purposes throughout the innovation process. Therefore, rather than choosing one construct, these different approaches are integrated into an umbrella term called ‘design experiments’. Design experiments are cycles of developing capabilities and competences of the entrepreneurial team; at the same time they are cycles of learning about the limitations and opportunities related to particular PM ideas. The outcome of a design experiment might be a prototype in the lab or field, or it might be a probe in real markets, which enables the team to learn about what it can actually deliver. While the purpose of a design experiment might be learning about the technology/product and its potential, it can also be generating alternatives and getting the commitment of stakeholders (i.e. demonstrating the proof of principle). In this study, the construct design experiment is used synonymously with ‘design cycle’.

Stakeholder interactions

This study deploys entrepreneurial decision-making theories (refer to section 3.3) in describing and explaining the product innovation process in new ventures (refer to section 3.5). Accordingly, stakeholder interactions are identified as a crucial activity that influences PM goals over time. Although effectuation puts fundamentally more important role on stakeholders in driving the innovation process, feedback from stakeholders is highlighted in causal processes as well. It is assumed that firms engage in stakeholder interactions in order to test the market viability of particular business ideas, as well as generating new alternatives. The feedback and commitment from stakeholders are likely to influence the subsequent decisions and actions of the firms. In this study, the construct stakeholder interaction is used synonymously with ‘stakeholder cycle’.

5.2. DESCRIPTIVE MODEL OF THE INNOVATION PROCESS IN NEW VENTURES

Based on the constructs introduced in the previous section, a generic model is proposed describing the product innovation process in new ventures (Figure 5.1). The model is used as a sensitizing framework for data collection and analysis, and is expected to be useful in describing the product innovation process in new ventures.

The descriptive model proposes that product goals emerge from two distinct forms of activity within new ventures: design cycles and stakeholder cycles. It is assumed that firms progressively define their PM combination by engaging in a series of design and stakeholder cycles. The outcome of design and stakeholder cycles is likely to influence the PM goals at varying degrees. While some design and stakeholder cycles will result in a change in PM goals causing firms to shift into alternative markets and/or engage in different product concepts, other cycles are expected to have no influence on the PM definition. Furthermore, not all stakeholder cycles result in a commitment. Therefore, a stakeholder commitment is illustrated with a dashed line in Figure 5.1.

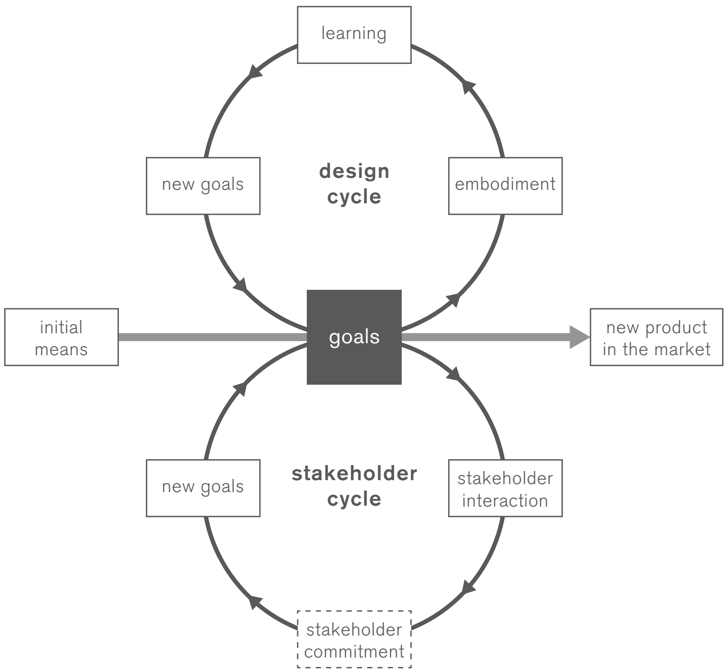


Figure 5.1. Descriptive model of product innovation process in new ventures

The descriptive model suggests that firms go into a series of design and stakeholder cycles enabling them to constrain product goals while expanding the amount of means into the venture. The design and stakeholder cycles might occur in parallel and/or consecutively. They may occur in varying frequencies and sequences. A stakeholder cycle might be the trigger of a design cycle and the outcome of a design cycle might be the trigger for a stakeholder cycle. The aim of the descriptive model is to illustrate this variety, as well as to introduce design as an important activity regarding product decisions and venture development. How the descriptive model might look over time is depicted in Figure 5.2.

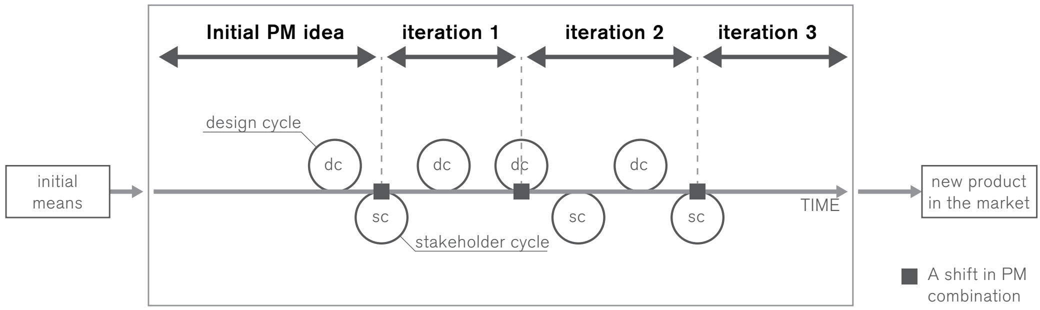


Figure 5.2. An illustration of how the descriptive model looks over time

5.2.1. Patterns

On the basis of the dynamic model of effectuation (Sarasvathy, 2008) and theories regarding experimentation, goals are expected to emerge from a number of design experiments and stakeholder interactions. Firms identify what they *can* do with their initial means and start *making* and *talking*, i.e. experimenting and interacting with a number of stakeholders, with the purpose of testing the feasibility of their idea, as well as acquiring necessary resources for innovation development. From this perspective, this study expects to find different patterns of innovation processes among the case firms. The processes are expected to vary in terms of the number and duration of PM iterations, as well as in terms of frequency, sequence, drivers and outcome of design and stakeholder cycles. To analyze and explain what drives these differences, the case firms have been selected to reflect this variety.

5.2.2. Operationalization

In order to observe and measure the product innovation process of firms, operational definitions of PM iterations, design and stakeholder cycles are clarified in the following paragraphs. A summary of operational definitions is presented in Table 5.1.

PM iteration

PM iterations refer to the variation in the definition of products and market segments a firm engages over time. In this study, product definition is operationalized from a supply perspective, and market definition is operationalized from a demand perspective. From a supply perspective, the variation in products is defined based on technological feasibility, i.e. technologies applied, solution principle and design configuration. Therefore, a shift in the product definition might represent a totally different product concept/application with totally different product architecture, or different product variants within the overall type (Lunn, 1972). From a demand perspective, the variation in markets (broadly or segments) is defined based on distinct demand functions and customer requirements in relation to a market or market segments. Furthermore, market segments vary based upon geographic, demographic or industry characteristics. A shift in the market definition represents a change in the broad/ general market (e.g. agriculture, automobile, tourism, transportation), or a change in the market segment (e.g. restaurant and retail stores within the broad food market).

The decisions that require the development of applications with totally different architecture and product variants, as well as address different markets and market segments are considered to be a PM iteration.

Table 5.1. Operational measures of product innovation process

Construct	Operational measure
PM iteration	A subsequent product concept/application a firm engages in for a particular market segment
A shift in PM combination	Decision to develop a different product concept/application and/or probe in alternative market segments
Number of PM iterations	Number of PM iterations a firm engages in
Duration of a PM iteration	Absolute time in years
Design cycle	Embodiment of a product idea into physical applications in a controlled environment (e.g. trial, lab/field test) or in real markets (e.g. probe)
Stakeholder cycle	Stakeholder interactions that a firm engages (with or without commitment)

Design cycle

Literature offers various forms of experimentation in order to decrease the uncertainty linked to innovations; such as trial and error, as well as probe and learn. Although experiments differ in terms of fidelity with respect to reality and the amount of learning they provide, a common feature of different forms of experiments is the embodiment of the product idea in the form of a physical application, i.e. a prototype. Prototypes are simplified versions of an eventually indented product idea (Thomke et al., 1998). Therefore, in this study a design cycle encompasses the development of a prototype and experimentation with it, whether in a controlled environment, in the field, or in a real market. Furthermore, different types of outcomes might be expected from a design cycle. If a positive outcome is achieved, firms are likely to continue with the same course of action, thus a change in PM combination is not expected. If a negative outcome is experienced, firms are expected to change the course of action, potentially leading to PM iteration.

Stakeholder cycle

Stakeholder interactions, which represent the lower cycle of the descriptive model, influence PM goals at varying degrees depending on the interaction and negotiation process. While some stakeholder cycles result in commitment, some do not. What is an actual commitment? Which stakeholder interactions and commitments count as a stakeholder cycle? Evidence for a strong commitment includes contractual agreements made with stakeholders, which involves a transaction in the form of goods, services, or funds (Silberzahn, 2011). Additionally, considering the resource scarce context of new ventures, non-contractual commitments in the form of time, knowledge, and capabilities are expected to influence the definition of PM combinations. Therefore, depending on the type of stakeholder (e.g. partner, potential customer, investor, supplier), a stakeholder's commitment might be in the form of time, knowledge, capabilities, as well as financial means. In return, entrepreneurs are expected to commit, which, in some cases, leads to a PM iteration. Moreover, it is also assumed that stakeholder interactions, which do not result in an actual commitment, influence the PM goals, in some case leading to a PM iteration.

5.3. EXPLANATORY CONSTRUCTS

The generic model introduced in the previous section is used to describe the innovation process in new ventures. The evolution of product goals has been illustrated through two distinct forms of activity: design and stakeholder cycles. In Chapters 2, 3 and 4, a multitude of factors were discussed, which may influence the product innovation process and explain the similarities and differences among product innovation processes in new ventures. These factors, as summarized at the end of the previous chapters are: expertise of the entrepreneur, resource position of firm, perception of uncertainty, type of innovation and sustainability motivation. In the following paragraphs, these factors are translated into 'explanatory constructs' that are expected to *explain* the different patters of PM iterations that firms engage in, as well as the differences in the variety and sequence of design and stakeholder cycles.

5.3.1. Type of opportunity

Both innovation and entrepreneurship literature highlight different types of innovation and opportunity based on levels of uncertainty. The degree of uncertainty is likely to influence the decision-making process, and consequently how the innovation process evolves. Accordingly, different management practices are recommended depending on the sources of uncertainty. Among others, entrepreneurs are confronted with two types of uncertainties: supply (technological) and demand (market) uncertainty. Silberzahn (2011) suggests that experimentation, particularly 'trial and error' process, is more effective in resolving uncertainties in relation to product and technology. This is due to empirical research that demonstrates how products might fail in the market, even though potential customers have reacted positively during the experimentation process, or how products prove to be successful despite negative market feedback (e.g. Kashani & Miller, 2003). Additionally, in the case of nascent markets, where there is no or little market information that predictions can be based upon, i.e. situations that involve high levels of market uncertainty, Sarasvathy (2008) argues that the main mechanism driving the goals is stakeholder commitments. Stakeholders who are willing to commit to the project are likely to reshape the goals in exchange (Wiltbank et al., 2006). Therefore, this study expects to find that different type of actions will drive the PM iterations due to the different levels and types of uncertainty linked to an innovation project. Furthermore, a situation is not uncertain per se. Therefore, PM iterations are not only influenced by an objective uncertainty, but also by how entrepreneurs experience and perceive uncertainty.

5.3.2. Perception of uncertainty

Some scholars have been suggesting to study uncertainty as individuals experience it. In this regard, Milliken (1987) defines uncertainty as "an individual's perceived inability to predict something accurately." The underlying beliefs of an entrepreneur about the future, i.e. whether it is measurable or true uncertainty, is likely to influence decision-making. Firstly, since it is assumed that design experiments are more effective in resolving technological uncertainty, whereas stakeholder commitments are more effective in market uncertainty, entrepreneurs are likely to engage in different types of actions depending on their perception of uncertainty. Secondly, entrepreneurs' perception of uncertainty is likely to influence their preference for using effectual and causal logic. Since effectuation is associated with early phases of the venturing process, some scholars have suggested a link between the use of effectual logic and a high level of perceived uncertainty (Reymen et al., 2015). In other words, a high level of perceived uncertainty is likely to influence scoping decisions. The use of effectual logic due to high levels of perceived uncertainty results in a widening the scope of venture, i.e. exploration of multiple opportunities. Therefore, the perceived uncertainty is expected to influence the number and duration of PM iterations, as well as the driver and timing of design experiments and stakeholder interactions. Additionally, entrepreneurs' perception of uncertainty is likely to decrease or increase on the basis of the outcome of design experiments and stakeholder interactions. As a result, this study expects to find different patterns of PM iterations over time for each case firm.

5.3.3. Entrepreneurial expertise

The use of effectual logic is not only influenced by entrepreneurs' perception of uncertainty, but also by their expertise. The theory of effectuation stems from Sarasvathy's (2008) research on expert entrepreneur behavior and offers a set of heuristic principles that expert entrepreneurs are observed to employ in situations of uncertainty. This theory suggests that both novice and expert entrepreneurs have a different attitude towards the future. While novice entrepreneurs primarily use predictive logic in decision-making process (i.e. seek for information to predict how the future will look and position themselves accordingly), expert entrepreneurs ignore predictive information and see the future as malleable. While the basis for action in novices is the predetermined goals based on predictive information, for experts it is a set of means under their control. Because experts are likely to predominantly use effectual logic, which is associated with experimental behavior (Chandler et al., 2011), the level of expertise of entrepreneurs is argued to be a source of differences between firms and expected to result in heterogeneous decisions concerning PM iterations.

5.3.4. Resource position

By integrating the traits perspective, Sarasvathy (2008) argues that some entrepreneurs, including novices, might be 'naturally' better at using effectual logic, "due either to innate traits and tendencies or to previous life experiences". However, it is assumed that the availability of resources is likely to stimulate the use of causal logic by novice entrepreneurs, whereas it does not have an influence on expert entrepreneurs. In other words, novice entrepreneurs are forced to use effectual logic when they have fewer resources. From this perspective, it can be argued that the resource position of a firm at a given time is likely to influence how product innovation evolves. It is expected that resource constraints cause entrepreneurs to use predominantly effectual logic; consequently they are likely to allow stakeholders to drive the innovation process and adapt a more flexible approach to the evolution of PM combination.

5.3.5. Sustainability motivation

Pursuing additional social and/or environmental goals is likely to influence the product innovation process. Bechicci (2005) suggests that a high level of motivation is likely to escalate the team's commitment, resulting in a lock into a certain course of action. Therefore, sustainability motivation is likely to influence go/no go decisions, and a firm's commitment to a particular PM combination. Sustainability motivation is described on the basis of three dimensions: (1) the type of sustainability issue they aim to address (i.e. social, environmental, or both), (2) the degree of priority of social and/or environmental goals in comparison to financial goals, and (3) the degree of change entrepreneurs aim to bring to a particular market and society (i.e. their market effect). In this study, the focus is on for-profit ventures that treat social and/or environmental issues as central to their core business. Since pursuing social and/or environmental goals is expected to influence the innovation process, a focus is given on the last two dimensions (2 & 3). However, as discussed in Chapter 4, the motivation of entrepreneurs is expected to evolve when they engage in the entrepreneurial process, and consequently the influence of motivations is likely to vary over time. Furthermore, a high degree of change that entrepreneurs aim to bring to a particular market might escalate their commitment, despite that their perception of uncertainty might be high. As a result, the differences in how entrepreneurs define their firm in relation to sustainability, and the scope of the market they aim to impact are likely to result in different patterns of PM iterations.

5.4. CONCEPTUAL MODEL

This section presents a conceptual model to explain the similarities and differences among new ventures' product innovation process based upon the constructs of the descriptive model. The model incorporates the explanatory constructs, as explained in section 5.3, that are expected to influence the product innovation process. This model will be used to study the relationship between the selected constructs and the central construct, i.e. product innovation process, which has previously been characterized by three constructs: PM iterations, design experiments and stakeholder interactions. This study expects that different constructs will influence the product innovation process in different ways. In the following section, the relationship among the explanatory constructs and the descriptive model is explained through propositions.

The conceptual model will be used as a guideline for the case study in the following chapters. The explanatory constructs are operationalized for observation and data collection as follows:

Type of opportunity. In this study, focus is given to products that radically deviate from products that are currently available, i.e. products that are new to the firm and customer. However, as discussed in Chapter 2, product development that builds on new technologies, involve higher levels of uncertainties in comparison to products that build on existing technologies. As a result, the type of opportunity is primarily measured from a supply side perspective, i.e. technological uncertainty. Technological uncertainty is measured by the number of patents a firm possesses, as well as the relative effort and time necessary to develop a working prototype based on a technology.

Entrepreneurial expertise. Entrepreneurial expertise is measured based upon the degree of prior venture experience, in terms of both the number of years and companies founded. The expertise of entrepreneurs will be derived from sources such as interviews and Linkedin profiles. Additionally, entrepreneurial expertise is expected to vary based upon a change in the composition of the venture team, and as such it is conceptualized as a varying factor.

Resource position. A firm's resource position is primarily measured in terms of the financial resources available to the firm. Since product development requires significant financial resources, this is expected to influence PM decisions and subsequent actions.

Perceived uncertainty. Perceived uncertainty represents the assumptions and expectations of a firm in terms of technical feasibility and market viability of a PM idea. Perceived uncertainty is expected to change based upon the outcomes of design experiments and stakeholder interactions, thus it is conceptualized as a varying factor instead of static factor.

Sustainability motivation. Sustainability motivation defines how a firm addresses an issue related to sustainability through its products in a particular market. Sustainability motivation is measured by the market ambitions of firms, and the degree of priority of social and/or environmental goals. The information on sustainability motivation is derived from sources such as business plans, mission statements, complementary company documents, as well as interviews with entrepreneurs.

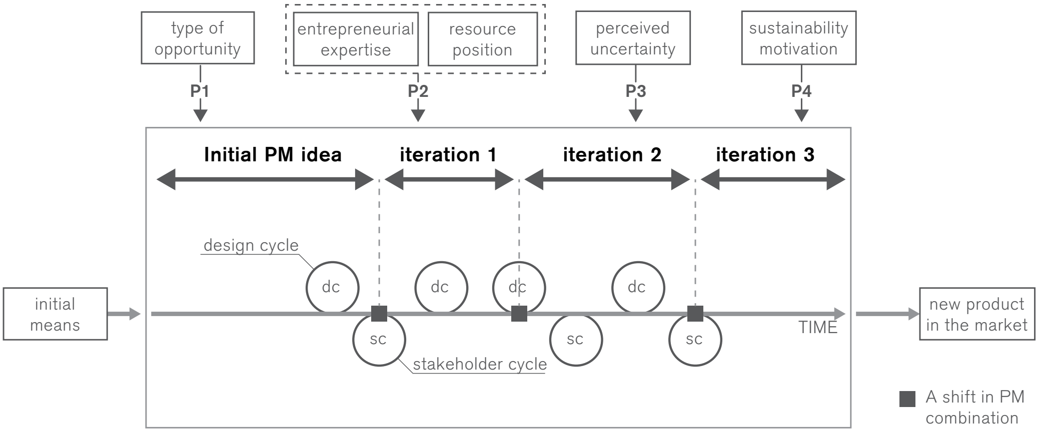


Figure 5.3. Conceptual model of the innovation process in new ventures and selected relevant process factors

5.4.1. Propositions

Propositions relate to the causal relations among the constructs under investigation, and are useful in further specifying the research focus and providing criteria for interpreting the findings (Yin, 2009). This section discusses the propositions, which are used for guiding the empirical exploration, in order to predict the influence of explanatory construct on the decisions concerning PM combinations.

Shifts in PM combinations

The first proposition addresses the implications of the type of opportunity for the innovation process. The conceptual model suggests that the shifts in PM combinations are driven mainly by two types of actions: design experiments and stakeholder interactions. It was suggested that the type of innovation and associated market and technological uncertainty have implications for the product innovation process. Firms are expected to engage in a series of design experiments and stakeholder interactions with different types of outcomes. Based on the outcome of these actions, firms are likely to continue with the same course of action or change it. Technical achievements or positive feedback from potential customers and partners are examples of positive outcomes, and technical failures or stakeholders refusing to commit are examples of negative outcomes. Thomke (1998) suggests that firms stop the trial and error process if an experiment is successful. If a negative outcome is experienced however, firms might continue experimenting with the same PM pair or shift to an alternative product concept or market. In the case of high levels of technological uncertainty, experiments are likely to result in negative outcomes, particularly in the early phases. Even though potential customers may welcome a product idea, the negative or mixed outcomes of design experiments might force firms to shift to an alternative concept or market depending on their competences, motivations and resources. Consequently, it is assumed that the PM goals are likely to be driven by the outcome of design experiments in the case of high levels of technological uncertainty.

P1. The definition of the product-market pair is primarily driven by design experiments in the case of high technological uncertainty.

PM iterations

The second proposition addresses the implications of the level of expertise and resources on the innovation process. Taking the link between entrepreneurial expertise and effectuation as a departing point, Chapter 4 proposed that expert entrepreneurs are likely to be more experimental and flexible with the definition of the PM pair in comparison to novices and corporate managers. This is because expert entrepreneurs are likely to focus on a set of available means and effects that can be created based on these means, rather than a particular vision or an end (Sarasvathy, 2008). In other words, experts are not fixed on particular goals other than broad economic (such as making money) or non-economic (such as solving a societal problem) goals (Sarasvathy & Dew, 2013). In contrast, novice entrepreneurs are expected to predominantly use causal logic. As a result, novices are expected to be less flexible with the definition of PM pair because they are more likely to commit to a particular opportunity as early as possible during the innovation process. However, their level of using causal logic is moderated by the level of available resources, as Sarasvathy (2008) suggests: "When entrepreneurs have few resources, they are forced to use effectual approaches, whether they prefer to or not – necessity being the mother of zero-resources-to-market, so to speak." Consequently, the following proposition is proposed:

P2. In comparison to novices, expert entrepreneurs are likely to engage with a higher number of short-term product-market combinations during the product innovation process. The novice entrepreneurs' approach is more likely to be moderated by the availability of resources.

Consequence of initial actions
The entrepreneurs' perception of uncertainty is expected to vary over time based on the outcome of prior actions (Meijer, Hekkert, & Koppenjan, 2007). The initial assumptions are likely to be incorrect, optimistic and idealistic; and therefore modified as the ventures engage in design experiments and stakeholder interactions. Learning from design experiments and feedback from stakeholder interactions is expected to cause a change in entrepreneurs' perception of uncertainty, and consequently influence the type of logic used by entrepreneurs and the behavior of firms. Because a high level of perceived uncertainty is expected to result in the widening of both a venture's scope (Reymen et al., 2015) and an experimental behavior of firms , the following proposition is proposed:

P3. A high level of perceived uncertainty that stems from the negative and mixed outcome of design experiments and stakeholder interactions is likely to result in a higher number of short-term product-market iterations, and vice versa.

Influence of sustainability motivation
This proposition addresses the influence of entrepreneurs' sustainability motivation on the product innovation process. As discussed in Chapter 1 and 2, sustainable innovations involve uncertainties regarding the social and/or environmental impact of particular PM combinations. New firms face decisions concerning which products to develop, and for which markets. A product in one particular market might not reveal similar sustainability benefits as it would in another market, due to different requirements or use scenarios. As a result, different motivations linked to sustainability are likely to influence the evolution of PM iterations. Although Berchicci (2005) suggests that sustainability motivation is likely to escalate the commitment of entrepreneurs to particular PM combinations, the literature does not offer an explanation on how the differences in the degree of change that entrepreneurs aim to bring to a particular market, influences the evolution of PM goals. As a result, the following tentative proposition is proposed:

P4. Sustainability motivation is likely to decrease the number of product-market combinations, while increasing their duration.

5.4.2. Research questions for the case study research

The previous chapters and the conceptualization presented in this chapter have enabled further specification of the research problem. The first research question has been addressed in chapter 2 and 3 (see Table 5.2 for an overview of research questions addressed in previous chapters). Based upon the insights from these chapters, this study has conceptualized the innovation process as a learning process, in which PM goals are primarily driven by design experiments and stakeholder interactions. Chapter 3 reviewed the entrepreneurship literature with a focus on the entrepreneurial process, in order to identify factors that explain the similarities and differences among the product innovation process in new ventures (RQ 2a).

Table 5.2. Overview of research questions addressed in previous chapters

Research questions posed in Chapter 1	Addressed in Chapter:
1. How can the product innovation process in new ventures be described?	**Chapter 2** reviewed the innovation literature and identified a number management practices based on linear and non-linear process models of product innovation. **Chapter 3** reviewed the entrepreneurship literature and the implications of entrepreneurial setting for the innovation process. It was concluded that the innovation process in new ventures unfolds in an iterative fashion driven by a series of design experiments and stakeholder interactions.
2. What explains the differences and similarities among new ventures' product innovation processes, in particular the evolution of product-market definitions?	**Chapter 3** reviewed the entrepreneurship literature with an emphasis on entrepreneurial process. The theory of effectuation was chosen as a theoretical lens to explain the product innovation process in new ventures. A number of factors were identified to explain how the innovation process unfolds in new ventures.
3. How does the sustainability motivation of the entrepreneurs influence the product innovation process?	**Chapter 3** reviewed the sustainable entrepreneurship literature on the implications of motivation of entrepreneurs for the innovation process.

Based upon the conceptualization in this chapter, an empirical inquiry will address the sub-questions of the second research question:

- What patterns of product innovation processes can be identified? (RQ 2b)
- What explains the similarities and differences in patterns of product innovation processes? (RQ 2c)

In addressing the third research question, Chapter 4 reviewed the literature on sustainable entrepreneurship with a focus on the motivation of entrepreneurs. It was concluded that entrepreneurs' motivation varies on two dimensions: (1) the degree of priority of social and/or environmental goals in comparison to financial goals, and (2) the degree of change entrepreneurs aim to bring to a particular market and society (RQ 3a). Although it is expected that sustainability motivation will escalate the commitments of entrepreneurs to a particular

PM combination (RQ 3b), literature offers limited insights on how the degree of change entrepreneurs aim to bring to society influences the product innovation process. In addition, the influence of the entrepreneurial process on the motivation of entrepreneurs requires further research. Therefore, the empirical inquiry will further address the sub-questions of the third research question:

- How does sustainability motivation influence the decision-making process, in particular the definition of product-market combinations? (RQ 3b)
- How does sustainability motivation evolve over time? (RQ 3c)

5.5. RESEARCH APPROACH

5.5.1. Case study research

As briefly discussed in Chapter 1, this study deploys a case study research, which is defined as "an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (Yin, 2009). This section explains the rational behind selecting a case study research for the purpose of this study, the unit of analysis of this study, and the role of extant theories in the research design.

There are a number of reasons, which make case study research a suitable research strategy for the purpose of this research. First of all, this study seeks to understand entrepreneurship as a process rather than an outcome, and adopts a process perspective in order to fully understand how new firms translate sustainable product ideas into new business, as well as the relationships between key concepts that have been outlined above. The majority of studies in the field of entrepreneurship focused on the use and development of quantitative methods before a profound understanding of the field was established (Suddaby, Bruton, & Si, 2015). Many scholars have expressed the need for qualitative studies that explore entrepreneurship from a process perspective. One of the motivations for this study was to address this gap and adopt a case study methodology with an emphasis on collecting qualitative evidence over time. The process perspective is suitable in addressing change processes and investigating the unfolding of events over time (e.g. Langley, 1999; Van de Ven et al., 1999). Process-oriented theories stress the importance of collecting fine-grained qualitative data in order to build a theory that is grounded in data (e.g. Langley, 1999; Strauss & Corbin, 1990).

A case study methodology is therefore found first of all to be useful due to its ability to trace changes over time and collect fine-grained data. Secondly, a case study research is well suited for answering the type of research questions posed in this study (e.g. 'how' or 'why' a social phenomenon works). Yin (2009) suggests that 'how' and 'why' questions are more explanatory in nature, and are likely to require case studies or experiments in order to understand the “operational links needing to be traced over time, rather than mere frequencies or incidence”. Thirdly, since experiments imply the manipulation of behavioral events in a laboratory or social setting, they are not suitable for the purpose of this study. On the contrary, a case study research does not require, or cannot manipulate actual behaviors, since the goal is to examine a contemporary phenomenon in depth in its real-life context (Yin, 2009). In other words, a case study research is an appropriate research strategy when the goal of the research is to explore how and why a phenomenon occurs in real-life, and under what conditions.

Another important component of a case study is the unit of analysis. The unit of analysis relates to the research questions of a study, and has implications for the research design and data collection strategy (Yin, 2009). In this study, the objective is to gain a profound understanding of product innovation process in the real-life setting of new firms, and what factors influence this process. Thus, the unit of analysis is the product innovation process in new ventures.

Furthermore, development of a preliminary theory before conducting both data collection and analysis, is an important step in case study research, as opposed to the ‘grounded theory’ which stresses solely inducting theory from case evidence and avoiding any a priori specification of theoretical proposition before collecting data (Eisenhardt, 1989; Yin, 2009). In this chapter, a theoretical framework has been developed by making use of extant theories in the areas of innovation management and entrepreneurship. This framework will be used in order to further specify the research problem, identify relevant constructs that are expected to influence the product innovation process in different ways, and develop propositions, which help to identify relevant information that needs to be collected from the case study. The propositions are then compared with empirical patterns from the case study. The models, constructs and propositions that are presented in this chapter offer a guideline for the next steps of the case study in the following chapters. The descriptive and conceptual model will be used for case study descriptions and analysis, based upon the operational measures defined in the previous sections of this chapter.

5.5.2. Case selection

Case selection is an important aspect of case study research. Unlike quantitative research, where the cases are selected based upon a ’sampling’ logic as commonly used in surveys, in qualitative research the selection of cases is purposive and requires a different logic (Yin, 2009). Yin (2009) distinguishes between two logics as criteria for selecting cases: literal replication and theoretical replication. While literal replication offers an explanation for similar results, theoretical replication predicts contrasting and different results for a priori expected reasons.

In line with Yin's suggestion, in this chapter a theoretical framework has been developed based on the extant theories, which entails two components. The first one is a descriptive model developed with the purpose of literal replication logic, and is expected to be useful in describing the product innovation process in new ventures. The second one is a conceptual model developed with the purpose of theoretical replication logic, and involves a number of factors that might be useful in predicting the similarities and differences among new ventures based on the constructs suggested within the descriptive model. For literal replication logic, two to three cases is sufficient; while for theoretical replication, four to six cases is desirable (Yin, 2009). Considering the time frame of this study, and the extensive time and resources process-oriented studies and multiple-case designs require, four new ventures have been investigated with the criterion to cover the range of dependent and explanatory constructs that were previously proposed.

In order to limit the variation between cases, three sets of criteria were used. Firstly, the firms needed to be new ventures with foundation based on a sustainable product idea and located in the Netherlands. Secondly, cases must be engaged in the process of developing a new product. Thirdly, the cases must exemplify the phenomenon of interest, i.e. they are dealing with radical innovation from a firm and customer perspective. In other words, the projects must involve high levels of technological and market uncertainty that stemmed from the challenge of developing technically feasible products with limited resources and capabilities, as well as potential customers' inability in expressing their needs in relation to new products. The performance of the firms was not considered as a criterion, since the innovation process of the firms was not yet completed within the scope of this study. In addition, the objective of this study was not investigate the factors leading to success or failure, but rather to gain insights into how new ventures manage early phases of product innovation.

In order to increase the possibility of identifying the factors that influence the phenomenon under study and explain the differences among cases, the variation between cases needs to be maximized (Yin, 2009). The selection of cases is based on a variation of the PM iterations, such as one of the constructs suggested within the descriptive model of the product innovation process (Figure 5.2). Although variation over the other two constructs of the descriptive model is plausible, it was not possible to gain an overview of the design experiments and stakeholder interactions of case companies before in-depth interviews were carried out with the company founders and employees. Therefore, the cases are selected based on their variation in the number and duration of PM iterations as depicted in Figure 5.4. The selected case firms are Solar Dew, Sustainable Dance Club, Evening Breeze and Vrachtfiets (Table 5.3). Solar Dew's product innovation process portrays a highly iterative pattern of PM combinations and a radical deviation from the initial PM pair. Similarly, Sustainable Dance Club's innovation process shows an iterative pattern, particularly with the definition of product concepts in the early phases and market segments in the subsequent phases. In contrast, Evening Breeze's product innovation process portrays a more focused approach and a smooth evolution of the definition of PM pair. Vrachtfiets' innovation process also shows an iterative pattern, particularly with the definition of markets. The firm's product concept has been evolving smoothly, i.e. mainly different product variants within the overall type.

Figure 5.4. Case selection based on the patterns of PM combinations

Additionally, variation over the independent constructs is plausible in order to investigate the influence of independent factors on the product innovation process. This study proposes five select explanatory constructs as factors that may explain the similarities and differences between the product innovation processes. The cases selected for the case study differ in terms of the type of opportunity, the level of entrepreneurial expertise, resource position, as well as their motivations in relation to sustainability. Although a variation over entrepreneurs' perception of uncertainty is plausible, it was not possible to gain an in-depth understanding of this construct before the data collection process. Moreover, the explanatory constructs do not only differ at the beginning of the innovation process as initial conditions, they also change and differ over time. How the explanatory constructs change over time will be described in within-case and cross-case chapters.

Candidate firms for the case study were initially sought among the participants of the 'EcoMind' project; a European project funded by the European Union's Interreg IVA 2Seas program, which is an intervention program that aims to address the specific support needs of SMEs who are seeking to develop innovative products and services for sustainability. Within the EcoMind project, 25 new ventures received support from intermediary organizations in the Netherlands during the period of 2009 and 2011. Nine out of the total 25 new ventures were in the process of developing a new product. Three out of the nine ventures showed interest in participating in this research and were therefore selected for the case study. Based on preliminary analysis of the three selected cases, one more case was subsequently selected which contrasted with the earlier ones. The flexible case selection process allowed cases within the case study to contrast sufficiently.

Table 5.3. Case characteristics

Case	Solar Dew	Sustainable Dance Club	Evening Breeze	Vrachtfiets
Year of founding	2000	2008	2006	2009
Initial PM combination	An irrigation mat for agro-businesses	Various product ideas for dance clubs	An air-conditioning system for ecologically conscious resorts in tropics	A cargo bike for students
Current PM combination	A household water application for the emerging market	An energy generating floor for multiple markets	An air-conditioning system for ecologically conscious resorts in tropics, as well as for the consumer market	A cargo bike for multiple markets A pick up bike for multiple markets A people mover for tourists
Status of product development process	Production trials (no sale)	Selling to various markets segments	Selling to two main markets	Probing in two main markets
Entrepreneurial expertise	Corporate manager (1998-2000) Expert entrepreneurs (2000-2004) Corporate manager (2004-2005) Novice entrepreneur (2006-2013)	Expert entrepreneur (2005-2007) Expert entrepreneur (2008-2013)	Novice entrepreneurs	Novice entrepreneurs
Resource position*	Akzo Nobel Investors	Subsidies Bank Revenues (as of 2009)	Personal resources Investors Revenues (as of 2009)	Subsidies One-off revenues
Type of opportunity (i.e. technology)	A new membrane technology Three patents filed	Electromechanical energy generator One patent filed	Modified existing technologies One patent filed	Existing technology
Period covered	2000-2013	2008-2013	2006-2013	2009-2013

** A description of the resource position of the case companies over time is provided in case histories in Chapter 6.*

5.5.3. Research quality

A common criticism of case study research is the challenge of making generalizations based on a small number of cases. In order to avoid such criticism and increase the quality of case studies, a number of measures suggested by scholars were taken. Among others, two important quality criteria for case study design are construct validity and internal validity. This paragraph offers an overview of such measures taken to increase the quality of this research.

Construct validity deals with the operational measures of the concepts being studied, as case studies are often criticized for being subjective due to insufficient operational measures developed for data collection and analysis (Yin, 2009). In order to avoid this pitfall, this chapter has defined the product innovation process in terms of three constructs, and provided operational definitions for each. Additionally, operational measures were defined for the explanatory constructs with reference to prior studies. Furthermore, strategies to increase construct validity include triangulation, i.e. using multiple sources of evidence (Eisenhardt, 1989), and having key informants to review the findings (Yin, 2009). In line with these suggestions, this study has used multiple sources of evidence (5.5.4), and asked a representative of the case companies to review the initial case descriptions, which was then used as an initial step in data reduction.

Internal validity concerns the causal relationship between two variables (e.g. how and why X led to Y, and whether factor Z might have in part, actually led to Y) and is particularly important for explanatory studies (Yin, 2009), such as this case study. A powerful strategy to increase internal validity is to use a pattern matching logic, "which compares an empirically based pattern with a predicted one" through propositions (Yin, 2009). The stronger the match is, the higher the internal validity is. According to this strategy, the influence of an independent variable over a set of dependent variables is predicted through an initial set of propositions. If an outcome matches the predicted values, and not alternative predicted values, strong causal relations can be concluded. Furthermore, if the results show a different pattern than the first case in a second augmented case with a different value for the same independent variable, conclusions can be strengthened, which enables theoretical replication across cases. Within this study and in line with Yin's suggestion, pattern matching logic has been used in relation to the dependent variables of the conceptual model. The cases have been selected to reflect a variety over both the dependent and independent variables, or constructs for literal and theoretical replication.

5.5.4. Data sources

A combination of multiple data sources is often desired in case study research in order to make triangulation possible (Eisenhardt, 1989), enable greater accuracy (Jick, 1979) and increase construct validity (Yin, 2009). Within the literature, scholars have suggested using a variety of sources to gather evidence. For instance, Pettigrew (1990) proposes three sources of evidence with their relative strengths and weaknesses. These include interviews, documents and observations. Most of the data collected in this research is qualitative, and is derived mainly from interviews and documents.

A summary of the quantity and type of data collected can give an impression on the depth of the data used for the analysis of the case study. The data within the case study includes about 40 hours of interview (resulting in more than 350 pages of transcripts), the majority of which were with entrepreneurs, investors and product managers, as well as 122 documents (including patents, company presentations, newspaper articles, progress reports, balance sheets and web articles, and digital photographs documenting prototypes and products). The following paragraphs discuss the rationale behind the selection of interviews and documents as data sources, and how they were used in data analysis.

Interviews

Interviews are one of the most common ways to collect data in case study research. Byrne (2012, p. 209) suggests that, “qualitative interviewing is particularly useful as a research method for accessing individuals’ attitudes and values - things that cannot necessarily be observed or accommodated in a formal questionnaire.” Interviews were considered to be highly effective in this study and were used to gain insight into the drivers, motivations and perceptions of entrepreneurs for engaging in particular actions and selecting PM combinations. In addition to this, interviews were also used to create a descriptive and chronological picture of the firms’ innovation process over time. Table 5.4 presents an overview of the interview data collected within the scope of this study.

Table 5.4. Overview of interview data collected

Case	Duration of interviews (hh.mm)	Number of pages (transcripts)
Solar Dew	21.28	180
Sustainable Dance Club	7.59	69
Evening Breeze	6.01	53
Vrachtfiets	8.45	56
Total	**44.13**	**358**

The data was gathered through semi-structured, in-depth interviews with various entrepreneurs and product managers involved throughout the innovation process of the case firms. The rationale behind selecting entrepreneurs and product managers as key informants was due to their knowledge about the project and extensive involvement in the decision-making process. As such, they provide a good opportunity to learn about the cases. Solar Dew's innovation process entailed a longer time frame compared to the other three cases. In this case, interviews with entrepreneurs and product managers previously involved in the venture provided additional insights into the earlier phases. Similarly, interviews with the founder of Sustainable Dance Club who passed the venture to a subsequent entrepreneur, and the previous product developer, provided valuable insights into the early phase venturing process. Prior to conducting the interviews, an interview guide was prepared based on the conceptual model, which consisted of nine key topics (see Appendix A). Within the first interview, entrepreneurs were asked about the design history of their firms. The main topics discussed during these interviews were: initial product ideas and their evolution, design iterations and the key lessons they provided, and the most influential stakeholders and their involvements. These first interviews lasted two hours on average. Based on the initial analysis of these interviews, the main design iterations and influential stakeholders were identified. In a second interview, and in some cases a third, entrepreneurs and product managers were asked for further details on their drivers, motivation and perceptions.

Documents

In case study research, documentary data collected in combination with other types of data can be important for triangulation (Punch, 2004). Complementary documents enable the researcher to validate findings from other data sources. Therefore, the interview data was complemented with additional documents provided by the firms. These involve company presentations, progress reports, balance sheets, patents, business plans, graduation reports of students that were involved in the process, brochures, product sheets and pictures, user test reports and movies. In addition, web articles, such as company websites and newspaper articles, were used as a supplement. These documents were useful not only for data triangulation, but also for reducing possible interview recall biases, and consequently depicting a precise picture of the evolution of PM definitions and creating an accurate description of the case histories.

5.5.5. Data analysis strategy and procedure

Data analysis is a key step in qualitative studies, and entails an iterative process to make sense of large chunks of qualitative data. Scholars have been suggesting diverse strategies and related techniques for data reduction and drawing conclusions. This implies that there is no one right approach in data analysis, and the purpose of research is an important criterion in selecting the most suitable approach (Punch, 2004). Additionally, Yin (2009) suggested that selecting particular tools and techniques should precede the selection of an analytic strategy for analysis. Two main objectives of this study are to: (1) describe, and (2) explain the product innovation process in new ventures motivated by an issue related to sustainability. For this purpose as suggested by Yin, two broad data analysis strategies are used to guide the data analysis: developing case descriptions and relying on theoretical propositions.

Developing case descriptions is a useful analytic strategy for identifying causal links in analysis. For this strategy, developing a descriptive framework from an initial literature review is an important step before data collection (Yin, 2009). In line with this suggestion, the current study has developed a descriptive framework based upon extant theories and a priori specification of constructs, instead of adapting a purely inductive approach as stressed by proponents of the 'grounded theory'. Therefore, as a first step in data analysis, case narratives were written in order to provide a descriptive account of the case firms' innovation process. A narrative strategy has certain strengths and weaknesses. The main strength of a narrative strategy is its accuracy, as it is "deeply rooted in the raw data" (Langley, 1999). In other words, "The contextual detail in the narrative ('thick description') will allow the reader to judge the transferability of the ideas to other situations. Indeed, good research of this type will often produce a sense of 'déjà vu' among experienced readers. The theorist who adopts this philosophy tries to avoid excessive data reduction and to present as completely as possible the different viewpoints on the process studied" (Langley, 1999). Despite its accuracy, this approach puts limits to the number of cases that can be studied and the generalizability of the findings. In order to overcome this challenge, a focus has been given on the constructs of the descriptive model in establishing an accurate flow of events, as well as creating and analyzing the historic descriptions of case firms' product innovation process. Additionally, a visual mapping strategy has been utilized to illustrate the evolution of the constructs of the descriptive model. Visual maps, or data displays as suggested by Miles and Huberman (1994), are useful in compressing and organizing voluminous and dispersed qualitative data (Punch, 2004), as well as the verification of theoretical ideas (Langley ,1999). They "allow the simultaneous representation of a large number of dimensions, and can easily be used to show precedence, parallel processes, and the passage of time" (Langley, 1999). In order to avoid researcher bias, informants were invited to check the initial case descriptions and give feedback. The case descriptions and visual maps provide a historic account for case firms' innovation process, and are presented in chapter 6 along with a within case analysis.

In addition to the case descriptions, propositions have been used to guide and orient the data analysis process. The propositions (5.4.1) have proposed causal links between the independent and dependent constructs of the conceptual framework. As a next step in the data analysis procedure, the interview data was coded based upon these preselected constructs in 'Atlas.ti', a computer aided qualitative data analysis tool. Coding is a process of "categorizing segments of data with a short name that simultaneously summarizes and accounts for each piece of data" (Charmaz, 2006). Depending on the research questions and the conceptual framework, the coding process can start with a set of pre-specified codes or conceptual categories, or alternatively codes can emerge from the data itself with no a priori pre-specified codes (Punch, 2004), such as in grounded theory. In the latter case, the coding process generally consists of three stages: (1) an initial phase of open coding with an emphasis on sticking closely to data, which results in a set of main categories; (2) a subsequent process of interconnecting categories with each other and sub-categories (i.e. axial coding), in order to produce a set of propositions; and (3) a final process of selective coding applied to the propositions through integrating and refining categories of previous stage (Strauss & Corbin, 1998). Since this study has extensively utilized extant valuable theories, as discussed in the literature review, and built a set of propositions prior to data collection and analysis, the coding process began with a set of pre-specified codes, i.e. selective coding. Miles and Huberman (1994, p. 63) suggested, “Whether codes are pre-specified or developed along the way, clear operational definitions are indispensable, so they can be applied by a single researcher over time and multiple researchers will be thinking about the same phenomena as they code.” In line with this suggestion, the operational measures defined in the previous sections of this chapter were used for pre-specified themes and codes. Subsequently, in applying a pattern matching technique, the empirical patterns were compared with the predicted patterns in the propositions (Yin, 2009). In this process, only the ‘code’, ‘sort’ and ‘retrieve’ functions of Atlas.ti were used. The outputs were then compared in tables to identify patterns. Chapter 7 discusses the cross case analysis based on the comparison of the constructs, as suggested within the descriptive model and explanatory constructs and propositions proposed in this chapter.

Chapter 6

Case Study Description

In the previous chapter, a descriptive model of the product innovation in new ventures was proposed as a framework for the case study research and analysis. This chapter provides a historic account of the product innovation process of the case firms based on the variables of the descriptive model. The product innovation process for each of the firms is categorized into phases on the basis of the main activities undertaken and important milestones such as change of shareholder/entrepreneurs, access to investors/customers and technical failures. For each phase, a detailed account of the product-market (PM) combinations the firms engaged in over time is described. The PM iterations are distinguished based on the operationalization discussed in section 5.2.2. Additionally, the drivers and outcome of design experiments and stakeholder interactions, and their influence on the subsequent decisions are explained.

The case firms are described in the following order: Solar Dew (6.1), Sustainable Dance Club (6.2), Evening Breeze (6.3), and Vrachtfiets (6.4). In each section, the case companies are described as follows: a general introduction to the firm, rationale behind its selection as a case, an overview of data sources, a summary of the PM iterations, and the team composition, financial resources and sustainability motivation over time. Subsequently, a detailed account of the PM iterations, design experiments and stakeholder interactions is presented. Finally, a within-case analysis is discussed in order to explain the shifts in PM combinations.

6.1. CASE: SOLAR DEW

The main interviews with Solar Dew have been conducted with Alexander van der Kleij (current product manager), Marinus Potter (one of the co-founders in 2000 and the lead product manager between 2004 and 2007) and Floris Croon (investor of Solar Dew since 2006). The interviews took place in May, June, July 2012 and March, August 2013. Research papers stemmed from field trials, progress reports, a Masters thesis related to Solar Dew and patent files all provided complementary data for this case.

The Solar Dew case was selected for its highly iterative PM development process involving high levels of technological uncertainty. The current PM definition of the firm shows a radical deviation from its initial PM definition. Solar Dew's innovation process consists of lab and field trials with immature versions of several consecutive PM iterations based on the sweating membrane principle as a platform technology, in an effort to find a feasible PM combination, without becoming a running business.

6.1.1. Introduction to the firm

Solar Dew is a Dutch firm based in Rhenen, the Netherlands. Solar Dew was founded in 2000 as a joint venture between Akzo Nobel, Business Factory and also participation from Wagening university and a founding private investor. Their vision was to develop water applications based on unique properties of a patented non-porous membrane technology, developed for clothing applications in the laboratories of Akzo Nobel in 1990s. Akzo Nobel is a global paints and coating firm and producer of specialty chemicals. Business Factory was a small private corporate venturing firm active in areas such as new materials and processes, renewable energy and food. During the foundation process, Akzo Nobel contributed a patent for a specific polymer. Over the past 15 years the idea has evolved from a technological innovation to an independent firm called 'Solar Dew International'. Throughout this period, the membrane technology, product concept and the target markets have undergone a variety of changes.

Summary of the PM iterations

Since the idea to develop an affordable desalination device first emerged within this firm, the definition of PM combination has gone through a number of changes. The ambition to capture the unique properties of the polymer led to the first concept called *irrigation mat*. Because the polymer sweated at high capacity and was salt resistant, using it for agricultural purposes was considered promising in many dry countries where saline water was vastly available. The product idea was a mat that consisted of multiple layers of plastic which would lie on agricultural lands, hence moistening the ground. This concept however, did not produce the expected amounts of water. The construction did not work efficiently as the mat sweats downwards and warm water rises. These findings led to the concept called *gutter system*. In the gutter system, the membrane was designed to be in a tubular form rather than a flat mat in order to increase the water output through upwards evaporation. The concept was a hectare flowing system aimed at purifying water produced from oil fields. The firm aimed at providing sustainable development opportunities for local communities, while providing oil production companies with diverse options for water re-use. This idea was abandoned due to low levels of water produced and the weakness of the membrane. At high water pressure and temperature as well as high oxygen levels, the membrane started to leak. Following this, Solar Dew shifted its focus from large-scale irrigation to small-scale drinking water applications. This led to a third concept called *black top collector (BTC)*. The BTC concept was designed as a household product for low-income countries and consisted of two modules; a black top solar collector for heating the water and a membrane unit for water distillation. Although the results were promising, the prototype was expensive and required a large surface area to produce enough water for its intended purpose. This led to the next generation of BTC, which was called *regenerative black top collector (re-BTC)*. In the re-BTC concept, the two modules (solar collector and membrane unit) were integrated into a single unit. Furthermore, re-BTC was designed to be a three-stage setup of BTC, in which energy released during condensation was used for subsequent stages, in order to increase the amount of water produced. The product would need to be filled with water on a daily bases, whilst brine should be removed weekly. Although the thermal efficiency of the product was found to be satisfactory, there were issues with creating a watertight product, as well as the membrane that was inherited from Akzo Nobel. This led the firm to their current activity, which is the development of a new membrane and design of the third generation of BTC, namely *flex-bag*. The flex-bag concept combines the membrane with a plastic reinforcement through a welding process. As a result of this modification, a considerable reduction has been achieved in the price.

Technology description

Solar Dew technology is based on a non-porous polymer membrane, which optimizes the natural processes of evaporation and condensation, relying only on the sun for its energy. Traditional membrane distillation techniques often involve the use of porous membranes, which are easily fouled by contaminants. Unlike these techniques that utilize porous to separate water from contaminants, Solar Dew uses a non-porous membrane to produce distilled water through a process called 'pervaporation', combining membrane permeation and evaporation (Figure 6.1).

Figure 6.1. The difference between a porous and non-porous membrane

The membrane is selective for water and does not allow contaminants to pass through to the other side. Therefore, the type or severity of the feed water does not have an effect on the separation performance and the quality of the produced water. Furthermore, the absence of pores reduces the risk of fouling, thereby increasing the lifetime of the membrane and the system.

Team composition

Throughout the whole process, since the perception of the idea until 2012, the firm's size fluctuated around six employees. Since 1998 until the foundation in 2000, a cross-functional team of approximately four people and two business experts carried out the trials. In this period, the project was managed by the corporate research director of Akzo Nobel. Between 2000 and 2005, a membrane expert team of four people and two business experts worked together on a number of experiments. Since 2006, when Solar Dew was taken over by private investors, the team has consisted of six people; of whom four are experts on thermodynamics, polymers and membranes working part-time on the development, one full time product manager and a new entrepreneur.

Business model

In the 1990s, Akzo Nobel had an established customer base and sales channels to provide micronutrients to agribusiness world wide. Therefore, the business idea behind the concept of the irrigation mat was to sell it to the agro-customers, who were buying nutrients from

Akzo Nobel. When the concept evolved from the irrigation mat to the gutter system in 2000, the business idea evolved into selling the gutter system to companies dealing with industrial wastewater streams. Since 2006, the firm's focus is on selling a household water application to customers in low-income countries using different business models. In particular, focus is given to working with local entrepreneurs, NGOs and governments, in which the Bottom of the Pyramid (BoP) customers pay for water instead of the product, which is owned and maintained by local entrepreneurs. Working with local governments and NGOs would enable Solar Dew to further refine their understanding of local needs and provide access to local markets in the early stages, while supporting the social objectives of participating NGOs and governments.

Financial resources

When Solar Dew started as a project in 1998, it was financed by Akzo Nobel. Subsequently, the firm was founded as a joint venture in 2000 between Akzo Nobel and Business Factory, as well as the minority participation of Wageningen University, a key private investor, and incentive shareholding by the key employees. Solar Dew primarily derived revenue from the private investors of Business Factory between 2000 and 2003 and from Akzo Nobel between 2003 and 2005. The burn rate of Solar Dew was approximately €1 million per year throughout 2000-2005. Since 2006, when the firm was taken over by Floris Croon and private investors, Solar Dew's burn rate is approximately €250,000 per year.

Sustainability motivation of the team

Since Solar Dew started as a project in the 1990s, it has been handed over a few times throughout the process; hence, the sustainability motivation of the team has been fluctuating. Overall, the team pursued social goals in parallel to commercial goals. This is reflected in the firm's aim to develop an affordable desalination application, initially for the agro-businesses, and later for the customers in emerging markets who do not have access to water or pay a high price for it. When Solar Dew began having financial problems in 2000, the priority of social goals appears to be lowered during the period between 2000-2004. Although the team's vision in the long-term was to serve people who are in need of affordable water, in this period the technological uncertainty that stems from the difficulty of translating the membrane technology into working applications, as well as the business uncertainties that stem from a lack of financial resources have led to the team to focus on wastewater reduction (i.e. formation water), in which the social value of the product was lower in comparison to agriculture and BoP markets. In 2005, when a new CEO was appointed, the team's focus shifted again toward the BoP market. Furthermore, this motivation appears to have increased with the involvement of a new investor in 2006. This is reflected in the amount of investment made between the period 2006 and 2013, and a low expectation of financial return even if the firm is successful. In summary, Solar Dew's motivation has been slightly fluctuating due to the involvement of different actors, and in situations of high levels of perceived uncertainty. Overall, the social mission has been a driving factor for firm's business activity.

Overview of PM iterations, design experiments and stakeholder interactions

An historic account of Solar Dew's innovation process is illustrated in Figure 6.2. The iterations of Solar Dew are categorized into four phases. The first phase (1998-2000) is characterized by lab and field trials with the aim of developing a proof of concept for an application for irrigation. The second phase (2000-2006) is mainly characterized by the demonstration project with Shell, as well as various quick and dirty applications developed in parallel with a broad scope aimed at a number of target markets. Solar Dew's third phase (2006-2009) is characterized by a number of lab and field trials of an application focused only on drinking water for the BoP market. The fourth and current phase of the process (2009-2013) is characterized by technology development for a specific application: drinking water for the BoP.

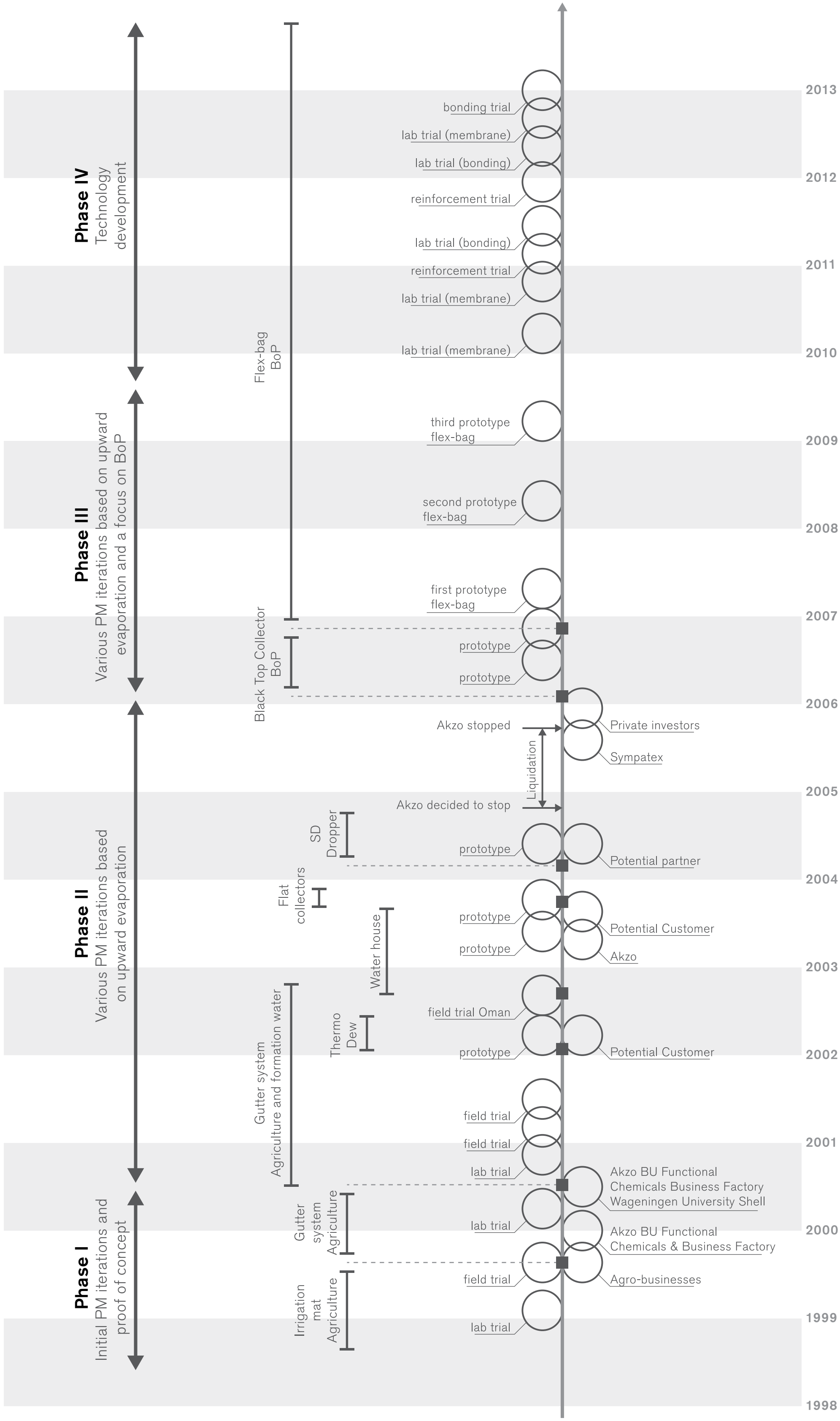
In the following paragraphs, each phase will be explained through a detailed description of the PM combinations and an overview of actions, in terms of stakeholder cycles and design cycles. The PM combinations, stakeholder and design cycles are determined by their centrality in interviews as well as complementary documents.

6.1.2. Phase I: Initial PM iterations prior to firm founding

In 1998, a brainstorm session was organized within the Membrane Research group in Akzo Nobel in order to explore possible applications based on unique properties of a non-porous polymer. The polymer sweated at high capacity and was salt resistant; therefore it could be used for seawater distillation. The corporate research director of Akzo Nobel was a socially motivated person believing in bottom-up initiatives. He was present in this brainstorm session and immediately took action. He created a cross-functional team of 3-4 people to make a small scoping program in order to explore possibilities of the idea. This lead to an application called *irrigation mat* (see Box 6.1). This agro-application was perceived to be interesting from a business perspective, as it required a large surface area and large amounts of plastics. Furthermore, Akzo Nobel had a customer base in agriculture. A scale model was tested in the lab in early 1999 in order to explore if the polymer could be used for irrigation (Figure 6.3). The scale model consisted of a sandbox of 1 m^2 in size with a simulated solar energy input of ~1000 kW/m^2 through a number of lamps for 12 hours a day (with 12 hours of darkness). This raised the temperature of the water to between 60 and 80°C and resulted in an estimated yield of 3 l/m^2/day fresh water. In dry regions with many sunny days and little precipitation, this could produce approximately 1.0-1.3 m^3 water per year per m^2. Effective irrigation is generally believed to require approximately 0.5 m^3 water per year per m^2 (Van Andel, 2000).

After the encouraging results of the scale model, the concept was further developed and tested in a field trial in Yemen during the second half of 1999, which took about 3 months. Although the prototypes worked, i.e. produced water, it did not deliver enough water for agricultural purposes under the windy and sunny conditions of the desert in Yemen. It was still not a proven technology and producing the mat was difficult; however many

Figure 6.2. Overview of Solar Dew's innovation process: phases and iterations »



Phase IV
Technology development
Phase III
Various PM iterations based on upward evaporation and a focus on BoP
Phase II
Various PM iterations based on upward evaporation
Phase I
Initial PM iterations and proof of concept
Flex-bag
BoP
Black Top Collector
BoP
SD
Dropper
Flat
collectors
Water house
Gutter system
Agriculture and formation water
Thermo
Dew
Gutter
system
Agriculture
Irrigation
mat
Agriculture
bonding trial
lab trial (membrane)
lab trial (bonding)
reinforcement trial
lab trial (bonding)
reinforcement trial
lab trial (membrane)
lab trial (membrane)
third prototype
flex-bag
second prototype
flex-bag
first prototype
flex-bag
prototype
prototype
Akzo stopped
Liquidation
Akzo decided to stop
prototype
prototype
prototype
field trial Oman
prototype
field trial
field trial
lab trial
lab trial
field trial
lab trial
Private investors
Sympatex
Potential partner
Potential Customer
Akzo
Potential Customer
Akzo BU Functional
Chemicals Business Factory
Wageningen University Shell
Akzo BU Functional
Chemicals & Business Factory
Agro-businesses
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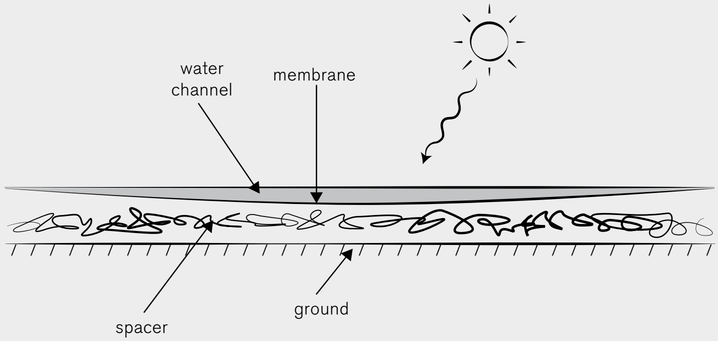
agro-businesses reacted enthusiastically asking Akzo Nobel to develop a solution with higher water output. As Potter explains, *"This is why it is such an interesting product. There was a letter from a high-ranking official of the court of Jordan saying 'we heard you had trials in Yemen, can you please come back and repeat these trials in Jordan? Because we need this water.' People in Yemen were highly enthusiastic about a company coming in, putting a black piece of plastic down there, and water coming up. Being pure as it is. The only problem was, it wasn't enough to justify the costs, but they wanted it."* Therefore, the team considered the technology as promising and decided to develop a new concept with higher water output.

Box 6.1. The concept of irrigation mat for agricultural purposes

The concept of *irrigation mat*, also known as 'pervaporation device' was designed as a means to obtain fresh water in countries with insufficient rainfall, ample sunlight and seawater or other salt-water sources. The mat was comprised of an upper sheet, which absorbed the sunlight; and a lower sheet, which was liquid water impermeable and water vapor permeable. The lower sheet was comprised of the non-porous membrane and a spacer reinforcing the membrane, improving the sheets mechanical strength. These two sheets formed a channel for holding salt water. The mat would be laid in the form of long strips between rows of plants, covering 50% of the soil. When the mat was filled with water and exposed to sunlight, the water in the mat was heated to 60-80°C and the non-saline water vapor would emanate at the bottom. Subsequently, the water vapor was condensed into non-saline water, directly dripping onto the ground. The ground would act as the condenser as it was cooled during the night. This way, the mat would desalinate and irrigate at the same time. At the end of the mat, the remaining water, which was increased in salinity, would be drained.

The process did not need additional cooling for condensation of pervaporated water as the cycle of day and night provided ample heat for pervaporation and sufficient cooling for condensation. This made the concept extremely simple from a design, production and maintenance perspective and at the same affordable (Van Andel, 2000).



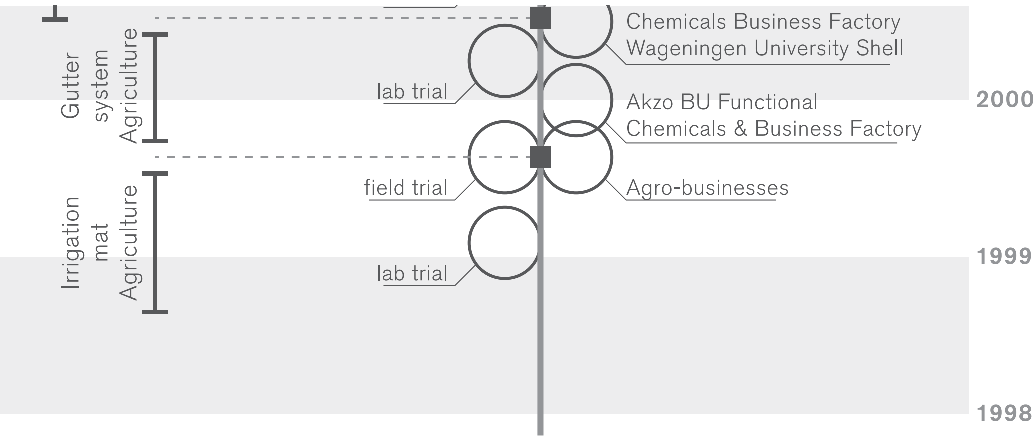


Figure 6.3. Overview of Solar Dew's initial PM iterations and actions undertaken

6.1.3. Phase II: PM iterations subsequent to firm founding

While working on a new application in 1999, the corporate research and development (R&D) within Akzo Nobel was dissolved and everything moved into business units. Many corporate projects could no longer be funded. In this period, Functional Chemicals, the most widely defined business unit within Akzo Nobel, became interested in the project (Figure 6.4). Their idea was to sell water applications to their existing agro-customers who were buying micronutrients. Meanwhile, the irrigation mat evolved into a new concept called *gutter system*, which worked based on upward evaporation in a tubular configuration and was expected to yield higher water output (see Box 6.2).

Functional Chemicals had many other businesses to run globally and the head of the unit wanted the Solar Dew project to fund itself and gain the attention they could not give.
In October 1999, the team came in contact with a venture capital firm called 'Business Factory'. After conducting a due diligence, Business Factory concluded that there were issues with the technical feasibility and business viability of the concept. The business model of selling plastics was not considered as a high earning business model without a patent. Since the previous patent filed was too narrow as it was based on a specific polymer, a new patent was needed for the gutter system. It was considered that the chances of getting a patent might be difficult due to competition in the field. Another technical uncertainty was the lifetime of the product, i.e. the combination of plastics, sun and wind was expected to create aging problems. Furthermore, another concern was that business was not viable without a 'preferably large' launching customer.

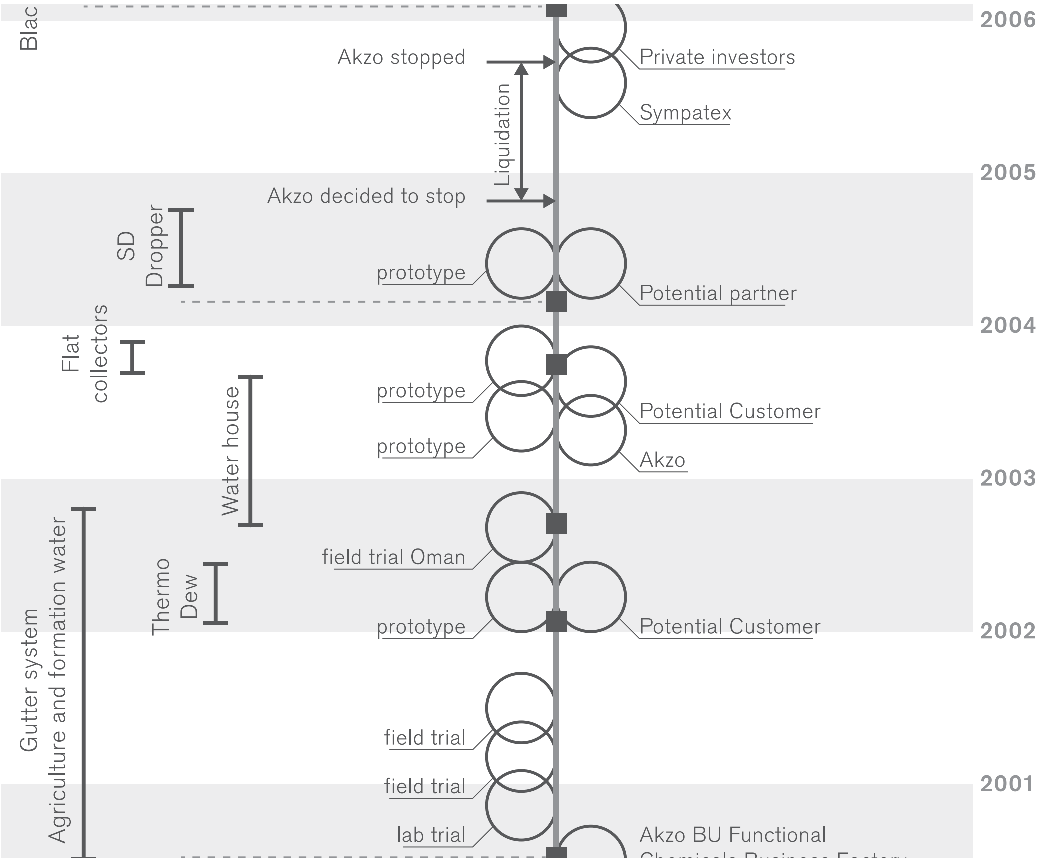
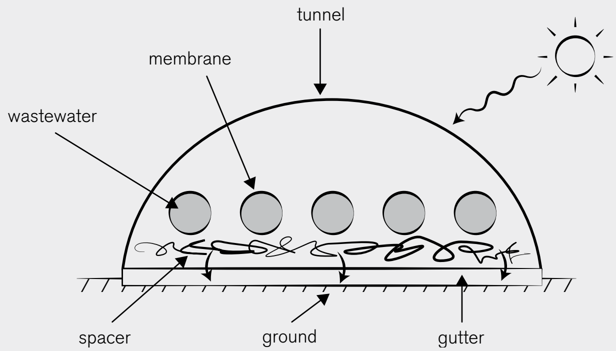


Figure 6.4. Overview of Solar Dew's PM iterations and actions undertaken in Phase II

During the due diligence at the end of 1999, Wageningen University carried out research for Akzo Nobel in order to explore suitable crops and locations around the world as well as the potential size of the market. During their research, Shell heard about the project and became interested as they were searching for technology alternatives for the treatment and disposal of produced water in Oman. Shell demanded a patent based on the gutter system, as they were interested in buying it once the product was successful. Meanwhile, in 2000 the team worked on the development of a scale model, which was then tested in a lab environment. The scale model comprised of an evaporation compartment, a storage tank (which was located above the level of evaporation compartment and connected to the evaporation compartment) and a vapor chamber (the upper surface of which is formed by an insulation skirt and the lower surface of sand). The evaporation compartment had a tubular shape and was made of non-porous membrane (see Box 6.2). The total height of the model was about 7 cm and the length was one meter. In a lab test, the model was exposed to: i) synthetic sunlight created in the laboratory with an output of 12 kWh/m²/day, imitated by irradiating the model during 12 hours followed by 12 hours darkness; and ii) natural sunlight with an output of 3.6 kWh/m^2/day. In both cases, the experiment was run over a time period of one week. The model produced 1 kg of fresh water per 24 hours in experiment (i) and 0.4 kg fresh water per 24 hours in experiment (ii) (Ter Beek & Wreesmann, 2001). Based on this model and experiment, the team filed a patent in January 2001. Business Factory approved to invest in the project, since the team had a patent within certain stages of approval and a launch customer. Shell Technology Ventures were considered to be important by Akzo Nobel and Business Factory investors. This way Solar Dew was founded in September 2000 by Business Factory, Akzo Nobel and Wageningen University as shareholders. While Akzo Nobel provided the human resources, i.e. a team of 6 experts, patents and one ton of polymer, Business Factory provided the financial means as well as two business experts, and Wageningen University provided the knowledge on suitable crops for such an application. The idea was to create a dedicated team for this project in the form of a new venture and lower the costs and risks involved until Akzo Nobel could take over, or the venture could be sold to a third party for the commercial scale-up.

Box 6.2. The gutter system concept

While in the irrigation map, the water flowed in between two sheets of plastic and evaporated downwards. In the *gutter system*, the water flowed in tubes of non-porous membrane and evaporated upwards. The membrane tubes were preserved in a transparent tunnel made of plastic, which acted as the condenser. In this case, wind could cool the plastic tunnel, helping condensation. The tunnel prevented water loss to the atmosphere. The black membrane tubes acted like solar collector. As the water was heated by solar energy, it sweated through the skin of the membrane and evaporated upwards towards the plastic tunnel. The evaporated water was contained in the space between the membrane tubes and the plastic tunnel. The vapor then flowed towards the colder plastic tunnel where it condensed. The condensed fresh water was then collected into the gutter of the system. The membrane tubes were placed on a spacer material in order to provide mechanical support as well as to prevent leaking. Dissolved salts and other chemicals were concentrated and remained in the tubes until discharged.



Initial trials

Following the foundation, Solar Dew together with Shell put most of its efforts in developing the gutter system for a demonstration project in Oman in 2002. The aim of the demonstration project was to explore the potential of the technology and further develop the gutter system for the purification of the large volumes of water produced in oil fields. The fresh water would then be used for sustainable development opportunities for local communities such as in agriculture and forestry, while providing Shell with diverse options for water reuse as an alternative to disposing wastewater into deep aquifers. In order to prepare for this demonstration project, the team first conducted initial lab trials in late 2000, which resulted in promising results (i.e. 90% water recovery). In the beginning of 2001 as a next step to build the prototypes for the Oman trial, they conducted a field trial in Canary Islands, which has similar weather conditions to the desert environment in Oman. In the Canary Islands, the results were lower than expected due to the wind and dust. Meanwhile, as Shell was interested in buying the technology once it worked, Solar Dew reluctantly invested in patents in countries where Shell was producing oil, in addition to the countries where there was a demand for pure water.

Qualification trial

Following the trials on Canary Islands, the team conducted a follow-up qualification trial using water produced from an oil field in south Oman. The qualification trial was a necessary condition for the scale-up trial in Oman and was a field trial executed in Oman during the summer of 2001. The system consisted of tanks for feed, purified water and brine, as well as three modules that contained long narrow steel gutters and membrane evaporator tubes lying on a spacer material and covered by a transparent plastics (Figure 6.5). The three modules covering an area of 1-3 m^2 were operational for a full year using the effluent of the reed beds, which were fed with formation water. The modules had no external energy input, using only solar energy. This trial demonstrated that the performance of the system in year-round weather conditions met the targets set for the quality and quantity of fresh water, i.e. pure water could be obtained in one step at an average production rate of 5 liter/m^2/day. This way the proof of concept had been demonstrated both through the trial in Oman in extreme summer desert heat and in moderate conditions on the Canary Islands.

Scale-up trial in Oman

The scale-up trial started in the second half of 2002 with the aim of demonstrating that a hectare flowing system could be run, i.e. the membrane was durable and the system was affordable and compatible with the alternative means of water purification. The trial was designed by using the oil field engineering practices. For instance, three 100 m long membrane tubes and gutters were installed at a 2° inclination in an airtight foil. Furthermore, a tank was placed on a platform creating six meters difference between the highest and lowest points (Figure 6.6). The membrane tubes were produced in the form of a carpet reinforcement, through blown film extrusion, i.e. the polymer was blown as a thin layer inside an automotive carpet, which supported the polymer. Besides the membrane tubes and gutter, the system consisted of a process control unit and pipe works to feed reed bed effluent to the system and collect produced water and brine. Performance was monitored and evaluated based on key parameters such as fresh water recovery and quality, integrity, logistics, crop type for fresh water irrigation, as well as cost of ownership of a scale up operation.

Figure 6.5. Field trial in Oman, 2001

Figure 6.6. Scale-up trial in Oman, 2002

The scale-up trial met the targets set for quality and quantity of fresh water, i.e. pure water could be obtained at a production rate of 4.7-5.2 liter/m^2/day. However, it became apparent that the membrane was not strong enough for six meters water pressure and was tearing. Furthermore, the team realized that the membrane in the form of carpet reinforcement did not work because the water that condensed on the cover foil was dripping on the membrane tubes due to the mechanical movement created by wind. As soon as there was water outside the membrane tubes, it started to leak, polluting the purified water. In addition, from a life-cycle cost and integrity perspectives, the team discovered that vulnerability of the cover foil and cleaning up gutters in case of a leakage were critical issues and needed to be addressed. In addition, the unit cost for water purification by the system was estimated in the range of 0.5-2.0 US$/$m^3$ reflecting the uncertainty in construction and durability of materials.

Furthermore, during the scale-up trial, the team realized that the dynamics of the project with Shell was not feasible due to differences in design criteria as well as development times. However the scale up trial continued due to the commitments given to Shell. In 2003, Solar Dew run out of money and Akzo Nobel started investing in order to complete the demonstration project with Shell. The trials in Oman were a succes as a demonstration of the technology, but failed as a scale-up project due to the fragility of the membrane at this scale of tubes of 100 meter length. At high water pressure and temperature as well as high oxygen levels, the membrane started to leak.

Various PM iterations parallel to and after the demonstration project in Oman

Although the demonstration project was the main activity of Solar Dew since the firm was founded in 2000 until Akzo Nobel took over in 2004, the team had also been trying out various PM combinations and building quick and dirty prototypes. The team aimed to develop applications, which were independent of feedstock, producing high quality and quantity water output and preferably fitting within the existing patents. Another criterion was the technical robustness that decreased the need for membrane replacement and increasing the lifetime of the product up to 3 years or longer. The significant prototypes were: thermodew for industrial wastewater (first half of 2002), waterhouse for industrial wastewater (2003), flat collectors for military purposes (2003) and Solar Dew dropper for drinking water for emerging markets mid 2004.

The *thermodew* concept (Figure 6.7) was developed to purify heavily contaminated water using waste energy in order to separate clean water form its contaminants. The *flat collectors* concept was a variety of the Solar Still concept aimed at scaling up for emerging markets as well as other niches such as military kits. It consisted of only plastic sheets, i.e. everything was made on a roll like air-mattress for the beach. It was made using welded and stitched flexible plastic foils. All tanks and tubes were integrated as welded chambers in the foils making the concept very attractive; however, the team could not manage to solve the problem of bonding laminated membrane to PVC foil without any pinhole leaks in late 2003. The *waterhouse* (Figure 6.8) concept was a follow up to the gutter system. Because the membrane in the form of carpet reinforcement was weak, Solar Dew contacted Sympatex, the team who initially developed the polymer and subsequently became an independent firm. Together with Sympatex, they produced the next generation of membrane through lamination during 2003. Although the laminate had a better tear resistance, it created other technical issues. For instance, attaching the membrane to hard parts such as tubes created short-circuiting and leakages.

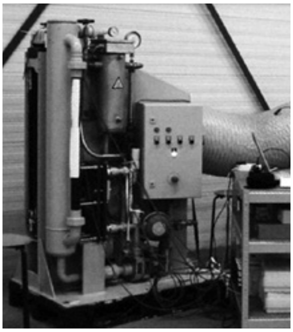


Figure 6.7. Prototype of thermodew concept (left)
Figure 6.8. Prototype of waterhouse concept (middle, right)

Solar Dew dropper and Akzo Nobel period

In 2004, Solar Dew started developing a new application called *Solar Dew dropper* with a focus on drinking water. On the one hand, Wageningen University came to the conclusion that irrigation was not economically feasible through the Solar Dew technology. The quality of the water the membrane produced was very high; however, the amount was not as high as expected. On the other hand, during this period Akzo Nobel took the lead as they started investing in the project, and the new CEO was interested in exploring opportunities in low-income markets.

Akzo Nobel was interested in investigating the total size of the market in India and China. An initial prototype was built in order to scope the market. The prototype consisted of the membrane in a box and a tank for contaminated water and was sent to Pakistan, to a local agent who was perceived as a potential partner (Figure 6.9). The membrane was based on no tear lamination reinforcement, which was previously developed for the waterhouse concept. The polymer plastic cover foil was the replaceable part; and the casing, tanks and tubes were meant to be the fixed parts and to be locally sourced.

The Solar Dew dropper received considerable attention within the local market. However, in November 2004 due to cost cuttings, Akzo Nobel decided to stop investing in Solar Dew and liquidated the firm; although it had met certain goals and the technology had a potential. The liquidation process was a period of inactivity in terms of experiments and lasted around a year.

Figure 6.9. Visual representation of Solar Dew dropper concept

Outcome of Phase II

In the period between 2000 and 2006, Solar Dew's main activity was the project with Shell and the development of the gutter System. Although the demonstration project with Shell was necessary to convince the investors and get finance and momentum, during the trial in Oman, the team realized that the dynamics of the project with Shell was not feasible; however, they could not stop the trial due to the commitments given to Shell. The partnership with Shell shifted Solar Dew's focus away from agriculture, drinking water or other socially motivated projects and slowed down the team's activities in developing other applications. Despite this, Solar Dew conducted small-scale lab trials for various PM combinations aimed at the combination of independent feedstock, high quality and quantity of produced water and a technically robust application that fits within the existing patents. In particular, focus was given to the development of an application for drinking water in solar rich areas, where infrastructure cannot currently provide a solution. The business model behind this idea was the central production of the high tech part, i.e. the membrane, and the local production of the parts, which could be made of wood and plastic.

Furthermore, a key outcome of this period was the regeneration principle, which was discovered during the trials of thermodew in 2003 and patented in 2005. The regeneration principle is being used in the current application of Solar Dew and increases the water output, which was one of the main challenges throughout the whole development process.

Although the second phase can be considered as a period of parallel developments and trials, the technical challenges (i.e. the weakness of the membrane and the low levels of water output) could not be overcome in a cost effective way.

6.1.4. Phase III: Various PM iterations

At the end of 2005, both Solar Dew and their patents were sold to a private investor and the business started again. The investor heard about Solar Dew from his brother who is a land and water development expert and had worked for many years in China within water related projects. Although their intention was to focus on the BoP market without expectations of creating a high earning business, they also saw potential in the Chinese market where they already had knowledge of the local culture and an established network.

As soon as the firm started at the beginning of 2006, an expert team was hired part time and worked on product development throughout 2006. Figure 6.10 gives an overview of the actions taken during phase III. The previous prototypes had suffered from wind, which created short-circuiting; and dust, which scattered the sun. The team decided to turn back the product, with the water evaporating downward, as in the first period trials. This way the product would be protected from the wind and the feed water would be at a higher chamber catching the sunlight directly. Therefore, the subsequent prototypes built during phase III were based on the principle of downward evaporation. Their first concept was called *black top collector* (BTC), and was designed as a household product for low-income countries (Box 6.3). The aim of this development was a 3-year lifetime for the membrane, which decreased the maintenance and operation costs dramatically. A first prototype was built during the first half of 2006 (Figure 6.11).

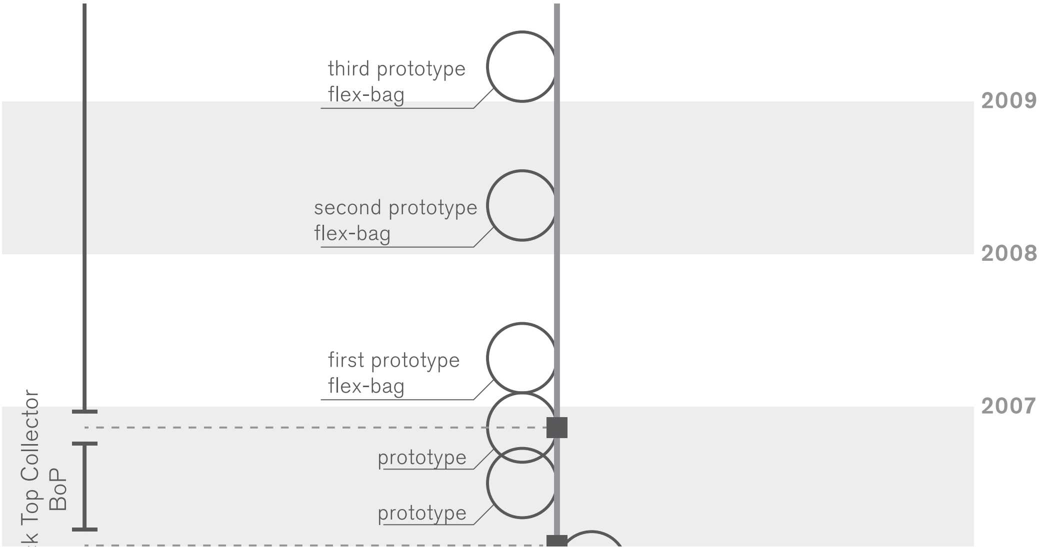


Figure 6.10. Overview of Solar Dew's PM iterations and actions undertaken in Phase III

Although the results were promising, the prototype was expensive and required a large surface area to produce enough water for its intended purpose. A system producing 20 L/day (minimum for a family of 4 people) would require a surface area of 12 m^2 and cost about €650. The main costs came from the large surface area of the solar collector, steel frames and the general set-up of the concept. The team concluded that the regeneration principle developed during the thermodew concept could decrease the surface area and increase the efficiency of the system (as the membrane area would double). By integrating the solar collector and membrane unit as in Solar Dew dropper, the costs could be decreased. Furthermore, the team concluded that developing watertight compartments (i.e. sealing) and the mechanical integrity of the system were important challenges that needed to be addressed.

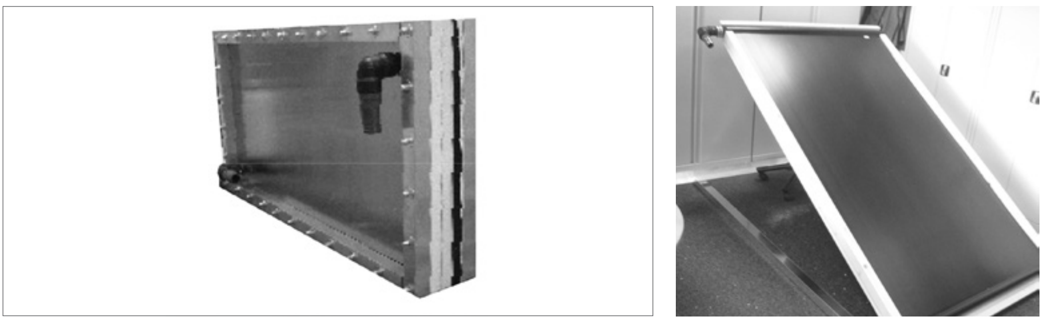
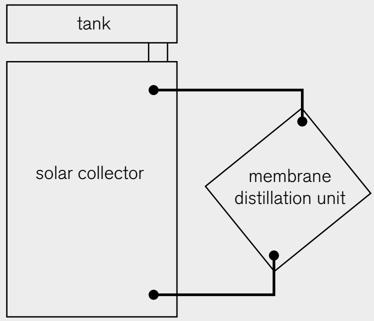


Figure 6.11. First prototype of the concept BTC

Box 6.3. Black Top Collector

The BTC concept consisted of two separate modules; a black top solar collector that was used to heat the water, which was then transported to a second unit producing the distilled water. In addition, contaminated water used for cooling the second unit was subsequently used as the feed water for the black top collector. The mechanical integrity of the membrane distillation unit was enabled through a plate and frame construction. Although expensive, it was the best available solution at the time.



Regenerative Black Top Collector (re-BTC)

The team then moved to the next generation of the BTC, which was called *regenerative black top collector (re-BTC)*. The re-BTC was designed to be a three-stage setup of BTC, in which the solar collector and distillation unit were integrated. The upper and lower plates were made of stainless steel, such that the entire chamber had a depth of approximately 20 mm (Figure 6.12). In addition, fins were placed vertically between the membrane and the lower plate as an additional form of support, which allowed water to roll down the condensation plate (Figure 6.13). The top steel plate was painted black and covered by a polycarbonate sheet to insulate and internally reflect the suns rays.

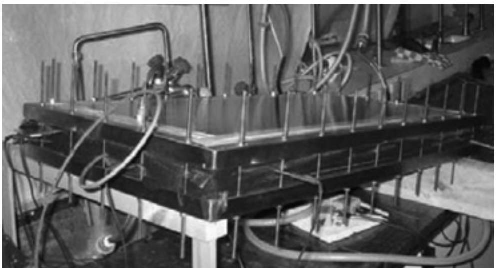


Figure 6.12. Prototype of re-BTC

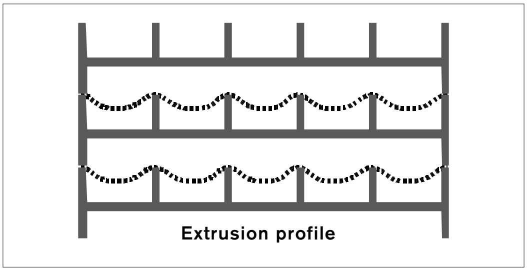


Figure 6.13. Construction of membrane distillation unit

When the upper chamber is filled with contaminated water and heated, the water evaporates downwards, where it condenses on the lower plate. The lower plate is essentially the upper plate for the next stage and so energy from the first stage is reused to heat the second stage. The lower plate of the third stage uses the feed water to provide cooling (Figure 6.14).

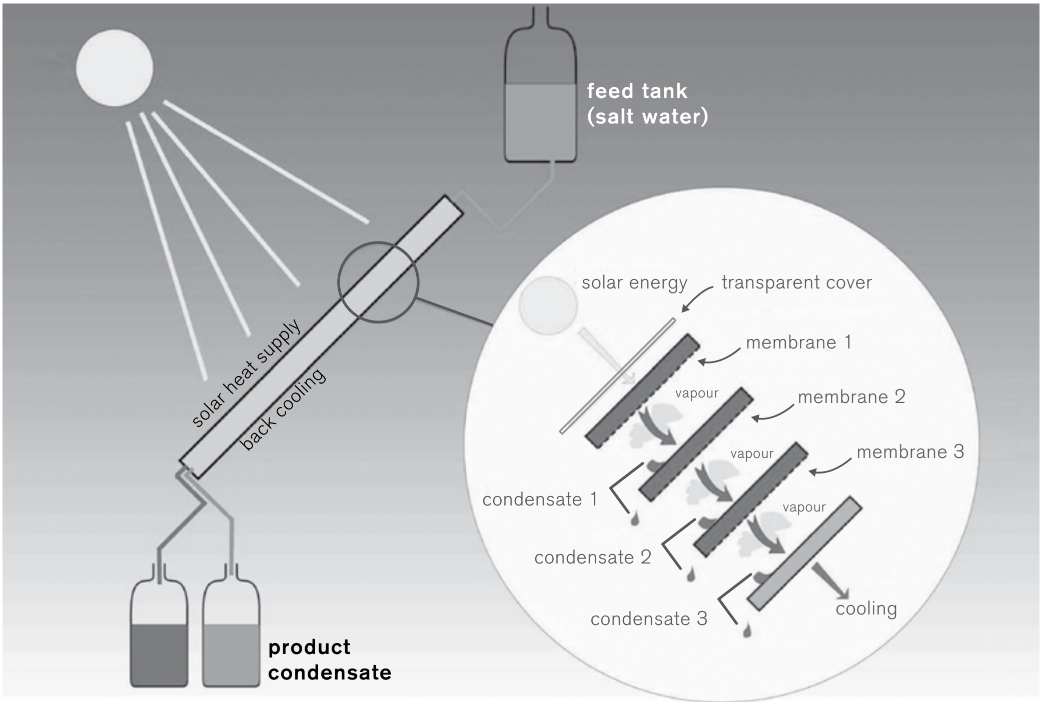


Figure 6.14. Working principle of re-BTC

A single layer setup could produce around 4.2 L/m^2/day, whilst a triple layer setup could produce approximately double that. This increase in production efficiency can be attributed to the regenerative nature of the setup, which improves the technology's energy efficiency. By reusing energy emitted through the process of condensation in the first layer, it is possible to heat the second layer, and so on.

The re-BTC was designed to be a household product, which could be placed on the ground or roof. The product would need to be filled with water on a daily basis, whilst brine should be removed weekly. Occasionally, the product should be completely flushed to eliminate all solid wastes, and the cover dusted in order for it to remain efficient. The membrane would then be expected to last approximately 3 years.

After extensive tests of the re-BTC, results showed that the thermal efficiency of the product, i.e. the energy that is directly converted into energy used for evaporation, was approximately 45%. This was found to be a relatively good value; however, it required improvement in the insulation in order to achieve better results. Moreover, creating a water-tight product with the plate and frame construction proved to be difficult. Another challenge was found in the tubes that transport the condensed water; the water tension in the tubes could block it, filling up the lower chamber.

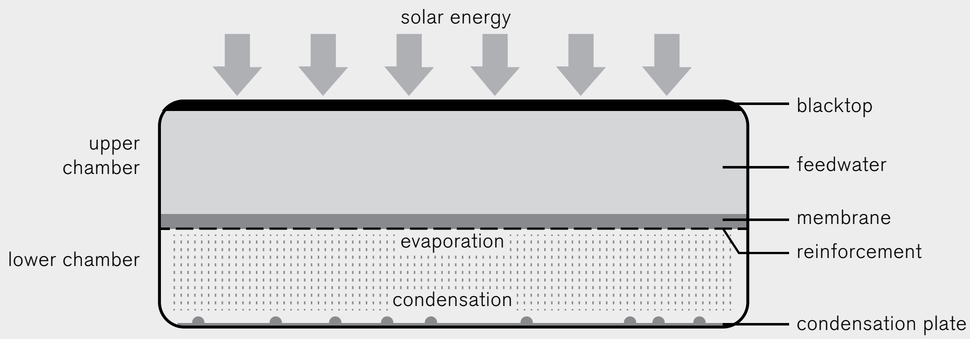
Flex-bag concept

The search for a low cost alternative led the team to experiment with various bonding technologies, in order to explore the possibility of combining the membrane with a top and bottom film in the form of a bag. These experiments led to *flex-bag* concept, which is the most recent incarnation of the Solar Dew Technology (Box 6.4).

Box 6.4. Flex-bag concept

Similar to re-BTC, the *flex-bag* consists of two chambers separated by a membrane. The contaminated feed water fills the upper chamber, which has a black top made of plastic. The feed water is heated by the sun and evaporates into the lower chamber. Water vapor eventually evaporates in the lower chamber when it hits the condensation plate. Instead of steel fins as seen in the BTC concept, a reinforcing material supports the membrane in order to cope with the pressures that exist within the product. Moreover, the flex-bag concept eliminates the necessity for building an expensive steel frame to support the membrane, resulting in a lightweight product. It is placed in a housing with a transparent cover in order to protect the product and improve thermal efficiency.

Ensuring that the product was properly sealed was time consuming and unreliable. Therefore, the flex-bag provides a closed structure, which does not require elaborate sealing such as in previous prototypes. As a result of this modification a considerable reduction (approximately 75% of the original) in the cost price has been achieved. The product can simply be placed on the ground or roof.



The team spent the first half of 2007 developing the first prototype of the flex-bag concept to see if it would work. A second (March-October 2008) and third prototype (first half of 2009) were built, in which a number of parameters, such as stress concentrations, water flow, weight, and others were optimized. In mid 2009, the team set up a long-term stability test with the third prototype in order to test various parameters, particularly the concentration of salt and its effect on water permeability. After one month of testing the membrane failed; there were leakages in the membrane, which was not expected by the team. The presence of water, high temperature and oxygen had led to chemical degradation of the polymer. Although the team was satisfied with the economics of the concept, the membrane was weak. In October 2009, they came to the conclusion that the membrane would not work under the requirements of Solar Dew. However, throughout 2008 and 2009, the team had worked on the details of the product design and the production system. As a result, they decided to continue with the project and search for alternative membrane. As the product manager recalls, "*This was a bad time. And after that we started thinking about alternative membranes. Because we have the whole product concept ready, you know. We just needed another membrane. How hard that can be?*" In the following months, they conducted research and small-scale laboratory tests to see if commercially available materials would fit their requirements. They concluded that most materials were either too expensive, or it was difficult to build a bag out of them (due to bonding properties of certain polymers). This led to the decision to develop a new, better membrane with higher water permeability, lower costs and easier manufacturing process. Bonding would be an important aspect, as it would enable a low cost product. One of the drivers behind this decision was all the effort already invested in developing the whole low cost solar desalination concept and its production system. Throughout 2010-2012, Solar Dew focused its efforts on R&D and lab trials to develop a new membrane.

6.1.5. Phase IV: Membrane failure and technology development

The overview of Solar Dew's actions throughout phase IV is illustrated in Figure 6.15. By 2009, the know-how of Solar Dew consisted of pervaporation and regeneration principles, as well as the non-porous membrane, which had failed in the long-term stability tests. When Solar Dew decided to develop a new and better membrane, the team had two ideas that could potentially work within the requirements of Solar Dew. Throughout 2010 they experimented with these two membrane materials to explore their behavior on certain parameters such as water vapor permeability, mechanical strength, pressure resistance, fouling resistance and homogeneity. As the membrane needed to be very thin for water vapor to pass through, the materials were coated on a reinforcing material in order to increase the pressure resistance. Although the results of the tests were very positive for the first option from a water vapor permeability perspective, and thus water output, its pressure resistance was much lower than required. They decided to stop with this material in August 2010. The second option was also not efficient in terms of water vapor permeability and pressure resistance; however, it was better than the first option and could be improved. A subsequent test was conducted at the end of 2010 on three different reinforcing materials, one of which was supplied by the membrane producer and consisted of two different layers of materials. The results highlighted two important issues. Firstly, the water vapor permeability was not as high as demanded due to the production process of the membrane supplier in their laboratory and could be improved on a roll-to-roll production line. A trial on a production line was much more expensive than in the laboratory. Secondly, the membrane coating on a two-layered reinforcement material had better mechanical strength and pressure resistance; however, it was more expensive than one layer alone, increasing the cost of the product. Therefore, the team decided to develop a cheaper reinforcement first, in order to justify the expensive trial on the production line of the membrane supplier. The initial reinforcement trial took place between February and June 2011 with two different suppliers on their production line but failed, as it did not fit to the requirements of the membrane supplier.

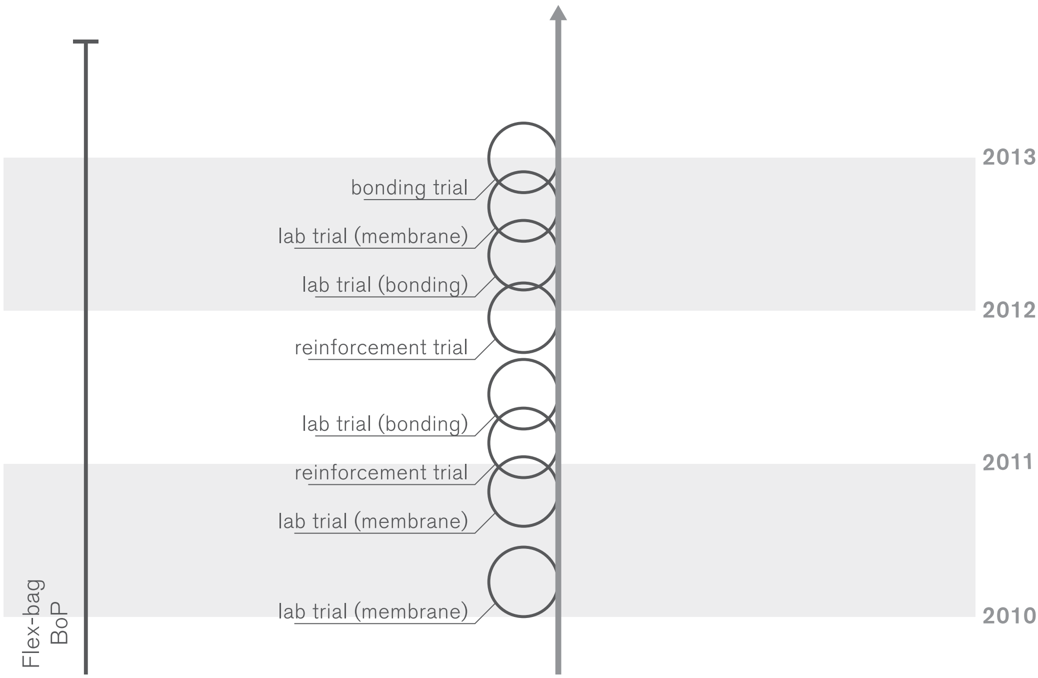


Figure 6.15. Overview of Solar Dew's PM iterations and actions undertaken in Phase IV

In the beginning of 2011, parallel to the reinforcement trial, Solar Dew conducted research into different type of bonding technologies, which was necessary for the production of flex-bag, e.g. bonding membrane, reinforcement material, top film, as well as the condensation plate, which is another type of plastic (see Box 6.4). They concluded that there were two potential bonding technologies. During the first half of 2011, they conducted a lab trial using both options with a focus on a number of parameters such as adhesion strength, water vapor permeability, stress concentration, pinhole resistance. Although the team had concerns about the strength of the flex-bag with the use of the first technology option, they decided to continue with it because of low investment costs. However, at the beginning of 2012 they decided to discontinue when they calculated the stress concentrations and discovered that the peel resistance of the system was much lower than required. Moreover, the results with the second option were more encouraging, although initial investment costs were much higher compared to the first. Nevertheless, they decided to continue with this second option, as it was the only one available.

As the first reinforcement trial failed in June 2011, a second trial took place between June 2011 and May 2012 with different suppliers and resulted in three possible reinforcement materials. The membrane was then coated on these reinforcements in different thicknesses resulting in seven different samples. In June 2012, a bonding trial carried out using these samples to determine the bond quality of the membrane and top film, as well as exploring the requirements for the bonding pattern and settings for the production of the bag. After bonding, the different samples were analyzed for peel strength and pinhole resistance. The main outcome of the test was a confirmation that it was possible to bond the top film to a membrane-coated reinforcement, achieving a high peel strength and pinhole resistance. Although they had developed an initial insight into the role of different settings, material combinations and configurations, they concluded that it was necessary to continue exploring how bonding could be achieved in a roll to roll process given that some crucial parameters would be very different to a lab setup.

Furthermore, the reinforcement samples produced in the first two trials as described above were tested in a membrane trial between July 2012 and February 2013 for a number parameters such as homogeneity, water vapor permeability, pinhole resistance, mechanical strength, salinity. The test results showed that the samples were not fully coated with the membrane causing significant risk regarding fouling and the quality of the produced water. This nullified the positive results from the previous bonding test, and in hindsight these tests had been carried out with partially coated material, partly due to the production process of the membrane producer. Based on the results of the membrane trial, Solar Dew decided to continue with two reinforcement materials and repeat the membrane tests but with a different set up.

During the membrane trial, a subsequent bonding trial took place in September 2012 on a pilot line in order to determine if the bond quality achieved in the first trial could be replicated in a roll-to-roll process. The trial failed as the welding process of the supplier was damaging the membrane, which has a very narrow window of bonding parameters of time, speed, pressure and frequency. The team came to the conclusion that they needed custom designed bonding equipment to test various parameters in a third bonding test.

In summary, when the membrane failed in 2009 and the team took the decision to develop a new membrane, there were mainly four challenges: 1) the type of the membrane material, 2) the ingredients of the reinforcement material and how to produce it, 3) how to coat the membrane material on the reinforcement and 4) how to produce the flex-bag.

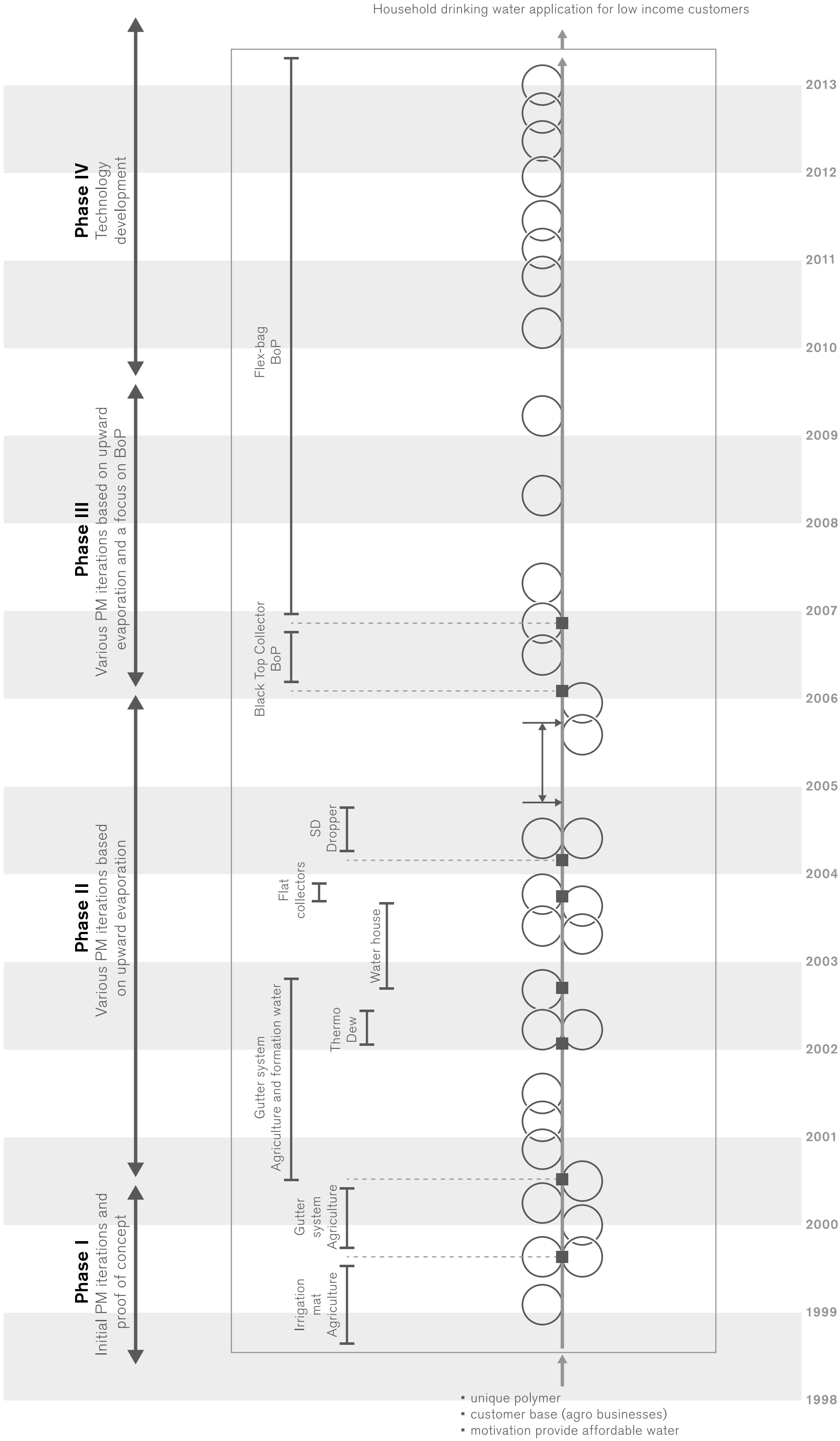
6.1.6. Conclusions Solar Dew case

As illustrated in Figure 6.16, Solar Dew's innovation process is categorized into four phases. In the first phase, Solar Dew put its efforts mainly in lab and field trials with the aim of developing a proof of concept for an application for irrigation. In this phase, the irrigation mat concept transformed into the gutter system due to the limitations of the irrigation mat in producing enough water for agricultural purposes. In the second phase, with the involvement of Shell, the team shifted its focus to developing the gutter system for the treatment of formation water. From 2000 till 2002, Solar Dew's main activity was the preparation for a large-scale field trial together with Shell, which took place in 2003. Meanwhile, the team conducted small-scale lab trials in order to explore the possibilities of using the membrane for other purposes, such as drinking water or industrial wastewater. This phase ended due to the lack of financial resources. A third phase started with the involvement of private investors. In this period, issues related to wind and dust stimulated to the team to redevelop the product and develop a concept based on downward evaporation. This way the product was expected to be more resistant to wind and dust. The plate and frame construction of the black top collector increased the cost of the product and created issues related to the water-tightness and efficiency of the product. This again led to a new concept, the flex-bag, in which a plastic housing was used instead of a steel plate and frame construction. This phase ended with the failure of the membrane during a long-term membrane test in 2009. Since 2009, Solar Dew has been busy with the development of a new membrane and the whole product concept around it. Table 6.1 gives an overview of Solar Dew's iterations.

Table 6.1. Overview of Solar Dew's iterations

Phase	Iteration #	Period	PM definition
1	Initial PM	1998 – 2000	Irrigation mat for agriculture
2	1	2000	Gutter system for agriculture
	2	2000 – 2003	Gutter system for formation water
	3	2002 – 2003	Thermodew, Flat collectors, Waterhouse
	4	2004	Solar Dew dropper
3	5	2006	Black top collector BoP
4	6	2007 – 2013	Flex-bag for BoP

Figure 6.16. Overview of Solar Dew's innovation process: phases and iterations ››


Household drinking water application for low income customers
Phase IV
Technology development
Phase III
Various PM iterations based on upward evaporation and a focus on BoP
Phase II
Various PM iterations based on upward evaporation
Phase I
Initial PM iterations and proof of concept
Flex-bag
BoP
Black Top Collector
BoP
SD
Dropper
Flat
collectors
Water house
Gutter system
Agriculture and formation water
Thermo
Dew
Gutter
system
Agriculture
Irrigation
mat
Agriculture
2013
2012
2011
2010
2009
2008
2007
2006
2005
2004
2003
2002
2001
2000
1999
1998
▪ unique polymer
▪ customer base (agro businesses)
▪ motivation provide affordable water

Definition of initial PM combination

Solar Dew was started as a project in a large multinational firm Akzo Nobel with the ambition to capture the unique properties of a polymer developed by Akzo Nobel laboratories. When the idea of using the membrane for water distillation first emerged in 1998, Akzo Nobel had a Membrane Research group that was led by a socially motivated corporate research director. Akzo Nobel also had an established agro-customer base due to the activities of business unit Functional Chemicals who was providing micronutrients to farmers in various countries. The selection of an application related to agriculture can be explained by the sustainability motivation of the corporate research director of Akzo Nobel, who aimed at developing an affordable desalination device to areas where there is no pure water available. Another explanation is the established agro-customer base of Akzo Nobel providing micronutrients to agro-businesses. The idea was to offer a solution to the agro-customer base of Akzo Nobel, but also to areas where there is no pure water available and sell micronutrients to the same channel.

Decision on initial actions

Initial actions of the project team were to conduct a series of design experiments (e.g. lab and field trials), which can be explained by the social motivation of the corporate research director of Akzo Nobel, who was leading the business unit Membrane Research with its own budget and decision power. He believed in the irrigation mat idea and decided to test its feasibility first in a lab trial, which was considered to be successful, and thereafter in a field trial, which proved to have limitations in terms of water output and construction of the mat.

Consequence of actions and subsequent PM iterations

Shift to gutter system for agriculture (iteration #1)
Although the initial lab trial proved to be successful, the field trial in Yemen showed that the irrigation mat could not produce the desired amounts of water and the construction did not work very well as the mat sweats downwards and warm water rises. Furthermore, the production of the mat was difficult. The team decided to continue with the Solar Dew project and develop the idea in a different application for agriculture, rather than looking for alternative markets or business models that fit the properties of membrane. This decision can be explained by the social motivation of the research director, the negative outcome of design experiments, the positive feedback of the agro-businesses during the field trial and the availability of financial resources that could be spent on the development of a new application (which could yield higher water output).

Shift to formation water (iteration #2)
In 1999, while developing the gutter system, the team realized there were issues with the technical feasibility of the concept. During this development, the Solar Dew project was deemed irrelevant due to cost cuttings and Akzo Nobel decided to pull out of the investment. The lack of financial resources forced the team into a series of stakeholder interactions

with different business units within Akzo Nobel and Business Factory (a private corporate venturing firm). Private investors were reluctant to invest in Solar Dew, due to the lack of a proof of concept and a launch customer. In that period, Shell heard about the project through Wageningen University, who had carried out research for Akzo Nobel to explore suitable crops and locations around the world. Shell was interested in Solar Dew project because they were searching for technology alternatives for the treatment and disposal of water produced within a project in Oman. Solar Dew was able to convince Business Factory to invest in a demonstration project with Shell and the focus shifted from agriculture to formation water. This shift can be explained by the commitments given to Shell and Business Factory and the motivation to develop the concept to a next level. Furthermore, the team still had the vision to develop affordable applications for low-income countries, but this ambition was overruled by the perceived technical and financial uncertainties.

Various short-term PM iterations (iteration #3)
Parallel to the demonstration project with Shell, the team had been trying out various PM combinations and building short-term affordable prototypes. These PM iterations can be explained by the social motivation of the team but also by the ambition to decrease the technical and market uncertainty of the project, which was perceived to be high in this period due to the mixed outcome of design experiments.

Shift to Solar Dew dropper for BoP (iteration #4)
Solar Dew had been gaining important insights from a series of design experiments between 2000-2004. Firstly, the outcome of the design experiments with various concepts showed that the applications were not able to produce the desired amount of water and the membrane was weak. Secondly, during the demonstration project the team realized that the membrane was not suitable for a large-scale application as required by Shell. Finally, the team concluded that the quality of water the membrane produced was very high, but the amount it delivered was not as high as expected. At the same time, the financial problems forced Akzo Nobel to start investing the project in order to complete the project with Shell. During this period, the new CEO, on secondment from Akzo Nobel, focused the development and getting first sales, and aimed at exploring the size of the BoP market. This shift can be explained by the commercial realism of a chemicals company, as well as the disappointing outcome of previous design experiments. It led to the discontinuation of short-term projects for waste-water concentration, but a positive business case of drinking water for the BoP as a potential market.

Shift to black top collector (iteration #5)
When a private investor took over in 2006, the team decided to develop a new application as they considered that the issues related to wind and dust could not be solved by small modifications on the Solar Dew dropper concept. Furthermore, the private investor and the team had a specific focus on the BoP market and aimed at developing a household product that could fulfill the daily drinking water needs of BoP families. Therefore, the decision to develop

a new application is an outcome of previous design experiments, as well as the sustainability motivation of the team.

Shift to flex-bag (iteration #6)

The efficiency of the BTC was found to be relatively good; however, it needed improvement. Moreover, the cost of the end product was too high for BoP customers. The search for a low cost alternative to BTC led to a new application. The reason why the BTC was not tested in different markets can be explained by the social motivation of the investors and their focus on the BoP market.

6.2. CASE: SUSTAINABLE DANCE CLUB

The main interviews with Sustainable Dance Club case were conducted with Stef van Dongen (initiator of the idea and the founder of Enviu), Alijd van Doorn (initiator of the idea), Michel Smit (CEO) and Trude Buitenhuis (Business Development Director). The interviews took place in May and November 2009, June 2010, September 2013 and April 2014. Research papers stemming from field trials, product sheets, as well as Masters theses and web articles related to Sustainable Dance Club provided complementary data.

Sustainable Dance Club was selected as a case for its iterative product development during their initial phase, which was followed by a focused product development in a broad scope of markets. Since its foundation, the firm has been going through a number of smooth product iterations and shifts in its target market. The innovation process of Sustainable Dance Club consists of early demonstrations with immature versions in an effort to find a feasible PM combination. In addition, the process shows a number of important instances regarding decisions to engage and pursue applications and shift to new markets and business models.

6.2.1. Introduction to the firm

Sustainable Dance Club was initiated in 2005 as a project by Enviu and architecture firm Döll, atelier voor bouwkunst (studio for architecture in English). Enviu is a Rotterdam-based network organization that aims to generate innovative business concepts and build partnerships to address local social and environmental issues. The project started with the aim of inspiring young people to adopt a sustainable lifestyle and making the clubbing scene more sustainable through reducing the environmental impact of clubs. Sustainable Dance Club as a firm started in 2007 when, amongst others, an energy generating dance floor was selected as the most promising product idea by the team. Since 2008, Sustainable Dance Club's main activity has been the development the dance floor, the rent and sales of it, as well as interactions with a number of stakeholders and potential clients. In addition, the firm uses a new trade name 'Energy Floors' as company name as of 2014, which is influenced by the firm's recent focus on the development of an energy floor for public spaces.

Summary of the evolution of the product concept

When the idea of the Sustainable Dance Club was initiated, the aim of the team was to develop a range of products and services, considering clubs holistically. Among others, the firm decided to focus on the development of a human-powered *sustainable dance floor (SDF)* due to the huge interest it had attracted in the media and also among the stakeholders of the firm. Since then, the concept, target market as well as the business model of Sustainable Dance Club have gone through a number of smooth iterations. Although the initial business idea was to sell the dance floor to clubs, since the beginning the firm was aware of the potential the rental market had for business. Various organizations were interested in renting the floor for their events and showcasing sustainability. Therefore, modularity was an important feature of the floor, which would enable Sustainable Dance Club to offer custom solutions. Another important criterion for the design was that the floor could convey a message inspiring young people to lead a more sustainable lifestyle. A feedback system through LED lights was incorporated within the floor in order to make human power visible to dancers as well as enhance the dancing experience. The product idea was that forces exerted on the floor could be converted into electricity through an electromechanical energy generator and stored in another medium or immediately used by other equipment.

Although the ambition of the firm was initially to sell SDF to clubs, the clubbing market did not take off and the business model transformed into a rental scheme for events and other organizations. Throughout 2009 and 2010 the main focus of the firm was the development and optimization of SDF. During this time, early versions of the floor were rented to various organizations. Meanwhile, the firm was getting requests for different types of energy generating floors from a number of organizations. Since the beginning of 2011, Sustainable Dance Club has been developing a new application, called *sustainable energy floor (SEF)*. SEF is designed as a large-scale application for public spaces where a large volume of people walked, such as stadiums, airports, and shopping centers. The technology used in SEF is the same as SDF however design considerations are slightly different. Firstly, SEF is designed to produce electricity from walking instead of dancing. This meant that less effort was needed to create energy from a SEF tile. Secondly, the SEF tiles are designed for mass production and significantly cheaper than the SDF tiles. Lastly, SEF is also designed to be waterproof for outdoor use.

Technology description

Figures 6.17 and 6.18 illustrate the working principle of the dance floor (1). On the floor surface (3) movable elements (4) are resiliently arranged and can be tilted and/or depressed by the weight of a user (5). If the dancer steps onto the movable floor element, it tilts about the pivot (19) and/or spring down. As a result, the arm (11) is pivoted about the pivot (13), the rack (12) of the arm (11) thereby driving the dynamo (18) via the gearwheel (15), the transmission gearwheel (16) and the third gearwheel (17). As a result, in the dynamo (18), electricity is generated electromechanically. This electricity is then transferred via a connecting cable (9) and connector (10) to the light elements (8). If the dancer moves away or steps off the element, the movable element (4) springs back into its original position. The arm (11) is also provided with a spring mechanism, so that it returns to its original position. This return movement may drive the dynamo driven again via the rack and the gears (Brezet, Van Doorn, Van Dongen, Randag, & Jansen, 2009).

Figure 6.17. Working principle of the floor

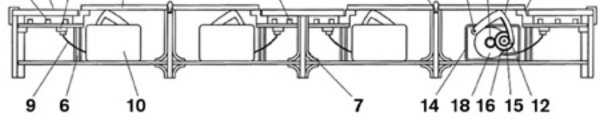


Figure 6.18. Sectional view of the floor

Team composition

Before their official foundation, an expert entrepreneur, who had identified the opportunity, was in charge of Sustainable Dance Club. In 2007, during the firm foundation, a new entrepreneur was appointed. Throughout 2008-2010, when development activities were at a maximum, a team of five people was employed, who carried out the design experiments and business activities; consisting of management, business development, financial administration, sales and marketing. As of 2012, the team has expanded to involve eight people. External advisers are occasionally consulted when making strategic decisions.

Business model

Van Dongen initiated the idea of the sustainable dance club in 2004, with the ambition to make the clubbing scene more sustainable and increase awareness among young people towards the concept of sustainability. The initial business idea was to develop and offer a range of products to clubs in order to decrease their environmental impact and offer consultancy services to help them achieve this. When an energy generating dance floor was selected as the most promising product idea in 2006, the strategy of Sustainable Dance Club was to sell their product to clubs. The business model was then shifted to a rental model in which intermediate customers (e.g. marketing and event agencies) rent the floor to end clients who want to showcase sustainability during public events. These clients consisted of corporate companies, educational institutes, museums, media companies and NGOs. As of 2010, the firm has put its efforts in optimizing the product technology for use in public spaces with large numbers of people walking through; such as stadiums, airports, railway stations, shopping centers, (public) buildings and city squares. The electricity produced through the energy floor can be fed back into the grid or used to power local systems such as streetlights or information and signing systems. A small amount of the energy can also be used to give feedback to users, e.g. by illuminating parts of the floor modules.

Financial resources

Sustainable Dance Club is currently owned by five shareholders; namely Enviu, Döll, the companies of the two employees and an investor. Before the foundation of the firm, Enviu received a grant called ‘SMOM’, which is given by the government to non-profit organizations developing projects related to sustainable development in the national and international context. Between 2008 and 2011, Sustainable Dance Club’s main revenue was primarily derived from banks, as well as the rental of early versions of SDF. Until the end of 2011, R&D expenditure of the firm reached €1 million. At the end of 2010, the firm received a EU funding totaling €226,000 for the development of the SEF. Sustainable Dance Club received €180,000 of this fund by the end of 2013. The firm generated revenue primarily from the rental of the SDF and has become profitable as of 2011; however, they are still paying back the bank loan.

Sustainability motivation of the team

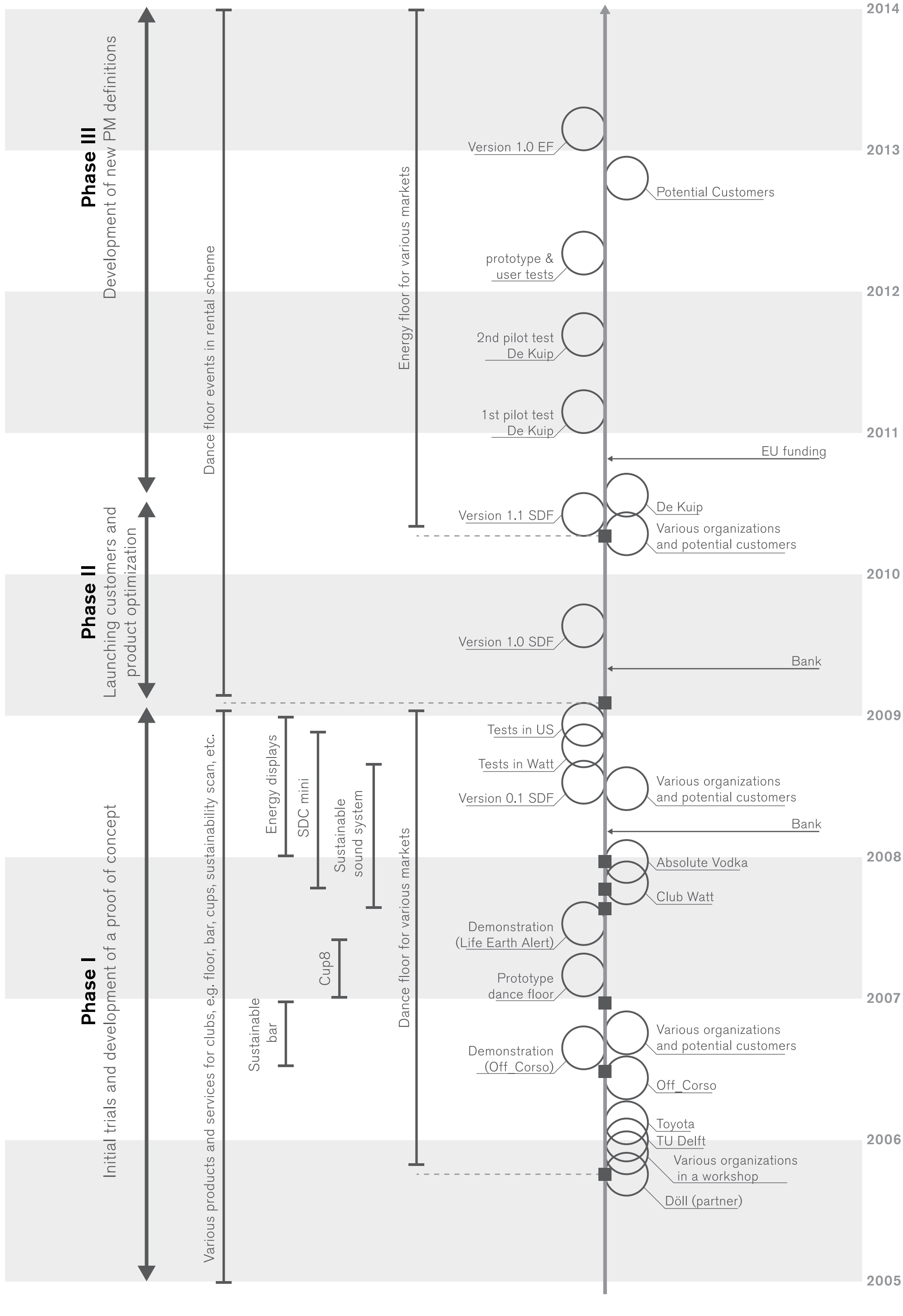
The idea of a sustainable dance club emerged from the motivation to bring sustainability into the attention of a wide audience. The ambition of the team was to create a worldwide network of clubs that inspire young people for a sustainable lifestyle. When the firm decided to focus on clubs, this focus was given to decreasing the environmental impact of clubs. This ambition then became an important mission of Sustainable Dance Club. Although a new entrepreneur had taken over the firm in 2007, this motivation continued until survival became an issue in 2009. The firm faced difficulties in selling or renting the floor to clubs and as a result, the focus was shifted to customers from other market segments that were interested in showcasing the concept of sustainability. Although the priority of their environmental goal had been lowered, the firm still put efforts in developing the floor with less environmental impact, which is reflected by the use of environmental impact assessment tools during its development. Since 2009, the main motivation of the team has been to convey the message of sustainability through the various versions of the floor, as well as its energy displays, which enabled the users to acknowledge the energy they can produce through dancing and walking.

Overview of PM iterations, design experiments and stakeholder interactions

An historic account of Sustainable Dance Club's innovation process is illustrated in Figure 6.19. The iterations of Sustainable Dance Club are categorized into three phases. The first phase between 2005 and 2009 is characterized by early prototypes that aimed at developing a proof of concept for an energy generating dance floor, as well as short-term affordable experiments conducted for other product ideas. The second phase throughout 2009, is characterized by early demonstrations and launching customers with the aim of developing legitimacy and credibility as a supplier of a product that can showcase sustainability. As of 2010, Sustainable Dance Club focused its efforts on the development of new PM combinations. The third phase of Sustainable Dance Club is characterized by a number of design experiments and demonstration projects, as well as a search for a number of markets and assessments of these market needs.

In the following paragraphs, each phase will be explained through a detailed description of the PM combinations and an overview of actions, in terms of stakeholder cycles and design cycles. The PM combinations, stakeholder and design cycles are determined by their centrality in interviews as well as complementary documents.

Figure 6.19. Overview of Sustainable Dance Club's innovation process: phases and iterations »



2014
2013
2012
2011
2010
2009
2008
2007
2006
2005
Phase III
Development of new PM definitions
Phase II
Launching customers and product optimization
Phase I
Initial trials and development of a proof of concept
Dance floor events in rental scheme
Various products and services for clubs, e.g. floor, bar, cups, sustainability scan, etc.
Energy displays
SDC mini
Sustainable sound system
Cup8
Sustainable bar
Energy floor for various markets
Dance floor for various markets
Version 1.0 EF
Potential Customers
prototype & user tests
2nd pilot test De Kuip
1st pilot test De Kuip
EU funding
Version 1.1 SDF
De Kuip
Various organizations and potential customers
Version 1.0 SDF
Bank
Tests in US
Tests in Watt
Version 0.1 SDF
Various organizations and potential customers
Bank
Absolute Vodka
Club Watt
Demonstration (Life Earth Alert)
Prototype dance floor
Demonstration (Off_Corso)
Various organizations and potential customers
Off_Corso
Toyota
TU Delft
Various organizations in a workshop
Döll (partner)

6.2.2. Phase I: Initial PM iterations and development of a proof of concept

The initial PM iterations and actions undertaken by Sustainable Dance Club are illustrated in Figure 6.20. The idea of bringing sustainability into a club environment was born from the ambition of van Dongen to bring sustainability to the attention of a broader audience. In 2004, van Dongen started Enviu, an organization that aims to develop companies with a social and/or environmental mission. Meanwhile, Döll, an architecture office based in Rotterdam was interested in developing projects in relation to sustainability. Through an intern working at Döll and at the same time a volunteer at Enviu, the two parties came together at the end of 2005. Although during that initial meeting, the idea of a dance floor was born, Enviu and Döll perceived the idea of a sustainable dance club as a good opportunity to develop a toolbox of sustainable design for clubs. The ambition of the team was to create a worldwide network of sustainable clubs that inspire young people to live a sustainable lifestyle. The initial business idea was to offer a whole package of products and consultancy services to reduce the environmental impact of clubs, but also to reduce costs related to electricity, water and waste. Besides the cost reduction, another incentive for clubs would be positioning themselves as a sustainable club and creating a unique selling point to new target groups. Sustainable Dance Club's strategy was to sell its products and services to clubs that aims to position themselves as a 'sustainable' club.

At the end of 2005 the team organized a workshop in Off_Corso, which was a prominent club in the center of Rotterdam. A flyer was designed for this workshop with a conceptual drawing of the dance floor. A number of stakeholders who might be interested in the idea of a sustainable dance club and provide input for the development of product and service ideas for clubs were invited. Besides the architects from Döll and volunteers from Enviu, a number of people from the Municipality of Rotterdam, Economic Board of Rotterdam and Off_Corso were also present. During this workshop a number of ideas were developed, and it was decided that the total concept of a sustainable dance club would be tested in Off_Corso. In January 2006, the team received a phone call from a movie production firm based in London, which was scouting innovative sustainable ideas for Toyota and was interested in the concept of the dance floor. The team got in contact with the Faculty of Industrial Design Engineering (IDE) at Delft University of Technology (TU Delft), in order to discover possible technologies that could be used within the floor. Based on the information received, the movie production firm developed a promotion movie of the dance floor, which was aired on Dutch television in July 2006, creating huge publicity. Meanwhile, in early 2006, a student from IDE, Anouk Randag, was involved in researching the interactive aspects and potential technologies that could be used in the floor, as well as to build a preliminary prototype.

As an initial step, a kick-off party was organized in October 2006 at club Off_Corso with the aim of showcasing the Sustainable Dance Club concept. A lot of effort was focused on products offered to the visitors as well as the interior design of Off_Corso. For instance, a wall was designed for visitors to place their used PET bottles in order for them to see the increasing consumption of bottles. Biological drinks and biodegradable cups were also offered during the party. During and following this demonstration project, the concept of a sustainable dance club received a huge amount of positive reactions. Clubs all over the world, event organizations, media and individuals showed interest in the concept. On the basis of this feedback, the firm tried but failed to collaborate with other organizations such as energy companies and fitness clubs, to co-develop the dance floor idea further

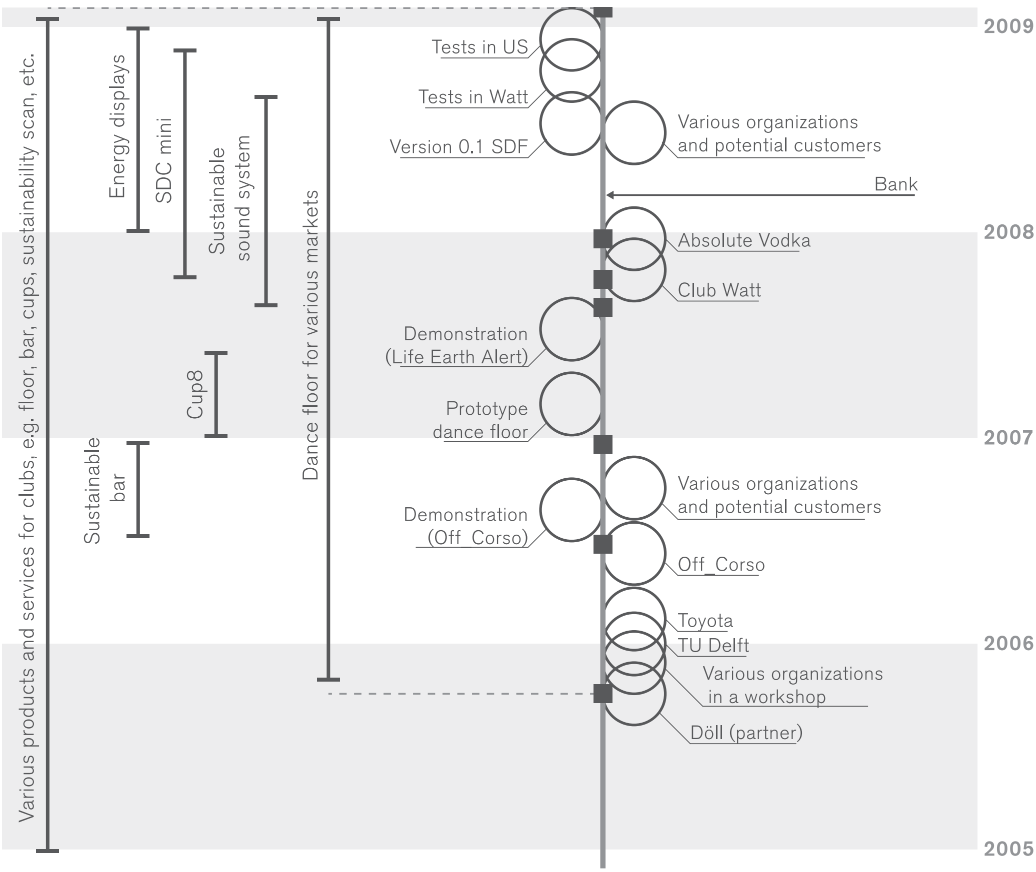


Figure 6.20. Initial PM iterations and actions undertaken

Meanwhile, throughout 2006, the team developed approximately 80 ideas that could make a club more sustainable. The team rethought the core activities of clubs and aimed at reducing the environmental impact of clubs and creating awareness among the club owners and clubbers by developing various products and services. Besides the energy generating dance floor, a number of concepts were developed throughout 2007 and 2008. Significant concepts in this period were a sustainable bar, Cup8, a sustainable sound system, and mini Sustainable Dance Club (mini-SDC). The *sustainable bar* (Figure 6.21) is a concept developed with the aim of reducing water, energy and waste consumption of bar systems in clubs and events. The *Cup8* (Figure 6.22) is a printable carton personal cup holder in the shape of an 8, designed to decrease waste by allowing the club/event visitors to use the same cup throughout a night or event. It can be worn on a belt, bag, or hat. With the *sustainable sound system* project, Sustainable Dance Club aimed at designing a wall that visualizes the sound. By using sound waves as an energy source, this wall could be self-sufficient. However, the available power captured in sound was not enough to create visualizations. Therefore, this project was abandoned with the recommendation for clubs to decrease their energy consumptions in relation to existing sound systems. The *mini-SDC* (Figure 6.23) is a compact club that allows a maximum of eight people to dance. It is developed with the aim of selling it to customers who are interested to showcase sustainability at an exhibition, event or party. When a visitor enters the mini-SDC, the sounds and visuals of the club are activated. The energy created is fed into the lighting of the club changing the brightness and intensity of the illustrations on the walls.

Figure 6.21. The concept of the sustainable bar

Figure 6.22. The Cup-8

Figure 6.23. The mini-SDC

First prototype of the dance floor and user test done by Anouk Randag

The assignment of Randag was to explore the possibilities of converting dance energy into electricity in a comfortable and attractive way, messaging sustainability to the audience. The main considerations in the design process of the dance floor were safety, dance-ability, ease of transportation, energy conversion technique and attractiveness of the design experience. Moreover, during the demonstration project, Sustainable Dance Club realized that renting the floor was an alternative business model, thus the modularity of the floor became an important criteria. The aim was to design a 'cool' dance floor which fits to the firm's mission: an innovative, transportable dance floor which is danceable and attractive for a large target group, gives feedback to dancers on how much electricity they are generating.

Randag researched various energy conversion techniques. Based on criteria such as production, maintenance, safety, use/dance-ability and energy conversion, she recommended an electromechanical conversion method. However, there was no electromechanical energy converter available at the time that could fit to the requirements of the dance floor, i.e. for a robust system converting 3.5-7W with a stroke length of 2 cm. Therefore, she built a prototype of two modules without a converter system. The prototype was built in order to simulate the conversion method and required input power. One of the modules was built by using springs (Figure 6.24) in order to test how people would theoretically experience the required input force to power the floor. The other module was built by using dynamo torches for damping simulation.

Figure 6.24. Springs within the first module

The outcome of this project was a concept called *FluxFloor,* a flexible design of several adjoining modules of one square meter (see Box 6.5). After engineering and detailing FluxFloor into a preliminary design, two modules of the floor were built and the intended energy conversion was simulated. The modules were tested during the 'Life Earth Alert Event 070707', which was the first of a series of worldwide concerts organized to combat climate change and advocate sustainable lifestyle. The organization behind the event was 'Save Our Selves' and it involved major partners such as former U.S. Vice President Al Gore, the Alliance for Climate Protection and Earthlab. Visitors to this event were invited to try the modules and were subsequently interviewed about their experience dancing on the FluxFloor. During this user research, various dances and movements were observed by people varying in age, weight and life style. The floor received great interest and positive feedback. The majority of people mentioned that they really enjoyed the dancing experience, although some people experienced the requested power to lighten the floor of the spring model and damping model as 'too heavy'. Assuming the energy conversion to be feasible in the way the dance floor is designed, a balance was found between dance-ability and power conversion, providing enough power and freedom of movement for positive design experience. However, because the prototype was built without a converter system, its degree of fidelity to reality can be considered as low (Thomke et al., 1998). Therefore, one of the conclusions of this design cycle was developing the need to develop a suitable converter system in parallel to further product development.

Box 6.5. The FluxFloor concept

During the design of FluxFloor, the target groups was chosen as the club owners or organizers of events who would buy or hire the dance floor in order to make their club/event greener. This led to the choice of a modular design, enabling clubs/events to remove or store the product and at the same time Sustainable Dance Club to rent the floor to a number of customers.

The square and translucent modules of FluxFloor were designed to contain flexible discs of 550 mm diameter. The discs are supported in the middle and can make a stroke length of 20 mm on each side by dancing on it. Throughout this stroke, the kinetic energy is converted into rotation by a generator. By dancing on various sections of the disc, the accompanying side of the square is illuminated in either red or blue. The light shines into the next module, as well as providing several interactive blending effects.

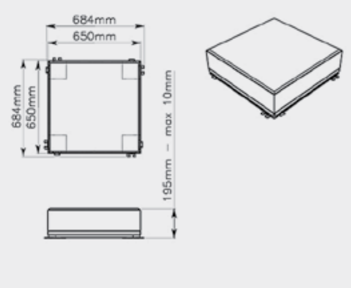
The first version (0.1) and subsequent demonstrations

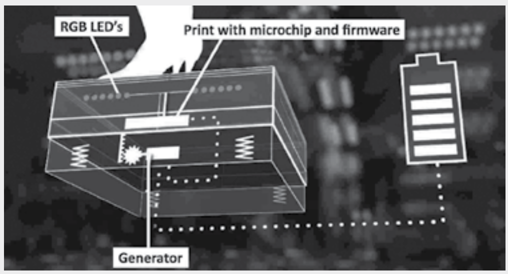
Towards the end of 2007, Sustainable Dance Club was founded and Michel Smit (the former director of club Off_Corso who was also an adviser of Sustainable Dance Club during the kick-off event in Off_Corse in October) became the director of the firm. Although the initial experiments resulted in positive feedback from potential clients, the technical details of the dance floor could not be worked out, i.e. there were issues with the technical feasibility of the idea. Soon after the foundation, the firm received a bank loan, which was mainly secured by the government in the form of an innovation credit. Meanwhile, two experts were hired to further develop the floor. One of these experts was Daan Roosegaarde, an interactive design artist who would explore the interactive aspects of the floor. The other one was Johan Paulides, who is an expert of the electro-mechanics and power electronics group of Eindhoven University of Technology and would work on the energy conversion system. Together, they designed the first series of the dance floor (version 0.1) (Box 6.6). This version was then leased to Club Watt, the first client of Sustainable Dance Club, in September 2008. Club Watt was interested in exploiting the club and experimenting with new products, one of which was the dance floor.

Following Club Watt, the floor was tested in the USA in December 2008 as part of a contract made with Absolut Vodka at the end of 2007. Absolut Vodka was scouting innovative ideas that combine art and sustainability and became interested in the idea of an energy generating dance floor. They wanted to be first in bringing it to the market in the USA and agreed to partly finance the energy tower, a new element of the SDF. The aim of the test was to explore how the floor worked in a club environment. Sustainable Dance Club, together with Absolut Vodka made three tests in a small club, a rock café and a big venue. The tests were successful and Absolut Vodka was interested in becoming a customer.

Box 6.6. Description of the first series

Version 0.1 consisted of three separate parts. Roosegaarde designed the top layer and the look, while Paulides designed the mechanical part. Furthermore, the electronics of the floor were designed and delivered by an engineering firm: Ymif. 66 square modules were produced with the size of 65*65*19.5 cm. The modules were designed to flex slightly when stepped on, which created a movement that is transformed into electric power by a small internal generator. Each module could produce between 5-20 watt per person depending on people's weight and activity (e.g. dancing or jumping). All modules were connected to a controller where the energy is stored and fed back to the floor modules when needed. The energy produced by movement was converted into electricity that makes the dance floor react to the dancer through the LED lights in an interactive way.





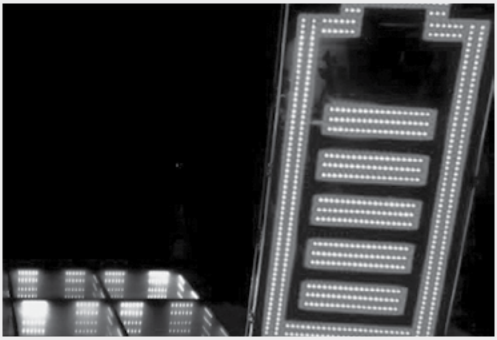
Box 6.6. Description of the first series (continued)

Dance floor experience

One of the important aspects of the SDF is its feedback system, which helps dancers understand that they are powering the floor. The basic feedback is the LED lights in the floor itself, which light up when being stepped on. Besides the floor itself, the firm was developing another feedback system, called the *energy meter tower*. The energy meter tower is made of aluminum, steel and transparent plastic and has a height of 2 meters. It can be placed near the floor and connected electrically either to the floor or the controller. It provides visual feedback of the amount of energy produced by the crowd dancing on the floor, creating a continuous real-time interaction between the clubbers on the floor, allowing every individual's actions to contribute to the collective experience. It has five rings of LEDs that light up when a certain amount of energy is being generated. The amount of energy generated is shown in percentages (0, 25, 50, 75 and 100%). The energy tower would light these levels all the way up to 100%, encouraging the dancers to attain the maximum energy level. This way the dancers are constantly reminded of the relationship between what they are doing and the world around them; this is what the firm calls a 'sustainable experience'.

A similar product is the 2.5 meters high LED battery that works in the same way the energy meter tower does. It shows the amount of energy generated in watt, with more visual impact.

Energy meter tower



LED battery

Outcome of Phase I

In the beginning when Sustainable Dance Club was still a project, the aim of the team was to develop a number of products and services for clubs in order to decrease their environmental impact, but also create awareness among young people. The idea of a dance floor was very attractive, so the team first started with the development of the floor. The initial prototype and demonstration was successful and showed that the dance floor would be the core product of Sustainable Dance Club. Although the rental model was an option, the team initially put its efforts in selling the dance floor to clubs. They began searching for clubs who would be willing to buy the dance floor and made a deal with Club Watt in Rotterdam towards the end of 2009. Club Watt was interested in a catchy new product. Furthermore, Absolut Vodka was interested in the floor, which was tested in US at the end of 2009.

Although the initial reactions of both Club Watt and Absolut Vodka were positive, Sustainable Dance Club soon realized that they would not be future customers as the floor is actually not an affordable product for clubs, and they would not be willing to make long-term investments. Their return on such an investment is only a few years and they had scarce resources to spend on new technologies. Following this conclusion, a rental contract was made between Sustainable Dance Club and Club Watt, although after 6 months Club Watt was in a conflict with its stakeholders about issues of funding and as a result decided to end the lease contract. Similarly, Absolut Vodka could not finance the floor anymore due to budget cuts caused by the financial crises of 2008; however, they were interested in buying the next generation of the floor.

From a technical point of view, the team soon realized that version 0.1 of the floor had some mechanical and electronic failures due to separately designed parts, i.e. the floor was not an integrated product and was not assembled in an industrial way. Furthermore, during the initial design experiments, the environmental impact of the dance floor was measured. The team realized that even partly powering the clubs was not realistic e.g. lighting. In addition, the amount of electricity generated was not enough to justify the amount of energy used for production of the floor.

6.2.3. Phase II: Launching customers and product optimization

The second phase of Sustainable Dance Club is characterized by a focused development of the dance floor and interactions with various customers from different segments (Figure 6.25). Although the focus of Sustainable Dance Club's business model was more on sales, the rental model was also a standing option. At the end of 2009, the team concluded that selling the floor was not a profitable business model. Around this time many pending deals were being canceled due to the financial crises and clubs could not afford to buy the floor. Furthermore, the dance floor was not yet an environmentally sustainable product. This pushed Sustainable Dance Club to shift its focus from selling the floor to renting it. In addition, the value proposition related to sustainability was shifting from 'decreasing the environmental impact of clubs' to 'creating environmental awareness to adopt a sustainable life style'. As van Dongen explains, "*When we saw that we could not sell the floor, the firm went into survival mode and rented out the floors*". Since the rental model was already an option before the development of the first series, the dance floor was designed to be a modular product. Throughout 2009, Sustainable Dance Club rented the early version of the floor to various organizations such as event and marketing firms, businesses, fairs and museums, who were mainly interested in showcasing sustainability. Some fixed installations that were done during this period include the Australian Museum in early 2009 and Eco House Brazil in April 2010 (Figure 6.26). Different numbers of modules were rented out depending on the requirements of the events and organizations.

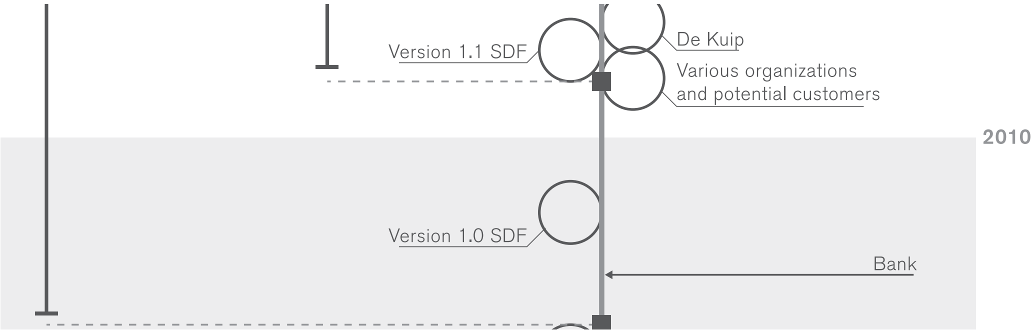


Figure 6.25. Design and stakeholder cycles throughout phase II

Figure 6.26. Fixed installations in Australian Museum (left) and Eco House Brazil (right)

In 2009, Sustainable Dance Club received a second bank loan in a similar arrangement to the first. Meanwhile, an in-house product designer, Eric van Duin, was hired and the subsequent version (1.0) of the SDF was developed during the first half of 2009 (Box 6.7).

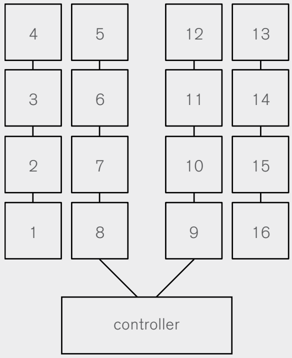
Throughout 2009 and 2010, Sustainable Dance Club mainly rented out the floor, for a wide variety of clients, but in some instances was able to make a sale. Projects ranged from permanent installations at museums, e.g. Miami (September 2009) and Philadelphia (March 2010), to pop-up events around the globe in Canada, China, Brazil and the United Arab Emirates.

Meanwhile in 2010, version 1.1 of the floor was being developed, which mainly involved the further optimization of the previous versions with better electronics and mechanical parts, easing the maintenance and increasing the lifetime of the product. Until the end of 2012, the firm had sold 17 SDF installations and rented the floor to various events in 69 different cities in 18 countries on five continents. This resulted in approximately 950,000 visitors who generated 2 billion joules of energy within 2012. Key projects in 2012 included an installation for a British energy firm 'EDF Energy' during the Olympics and Paralympics and for a Spanish radio station 'Los 40 Principales' for a 3-months long tour in 30 clubs in 30 cities in Spain (Figure 6.27).

Figure 6.27. Installations in Olympics and Paralympics in London (left) and installations for Los 40 Principales in Spain (middle and right)

Box 6.7. Description of the Version 1.0

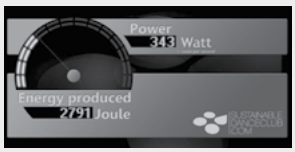
The main difference of version 1.0 from its predecessor was that the top layer and the mechanical part was integrated into one product. It is more industrial and ready for use. It is also more efficient, producing 35 watt of sustained output per module. The dance floor modules are 75*75*20 cm and are connected to each other in order to create a small power plant producing a maximum of 1400W. The dance floor modules are watertight and therefore can be placed outside as well.



Up to 40 modules can be connected to a controller that stores the energy produced by the dance floor modules in a battery system. The energy used to power the LED lights in the modules. Additionally, when the battery is empty, the electricity grid powers the modules.

Dance floor experience

Besides the development of version 1.0, the firm was developing a software application, called the digital energy meter, which shows both the instantaneous power (in watt) and the total power produced (in joule or watt*second). This software can be displayed on any screen, preferable large and in high resolution.



6.2.4. Phase III: Various PM trials with Energy Floor

Since the beginning, Sustainable Dance Club was getting requests for different types of floors, but until 2010 the firm's main focus was the development and optimization of the SDF. In 2010, Sustainable Dance Club aimed at capturing the value of its technology in a number of other markets based on the feedback received throughout the whole development process. This stimulated the idea of using the technology at locations where large volumes of people walk, such as stadiums, airports, railway stations, shopping centers, (public) buildings and city squares. This led to a new application called *sustainable energy floor (SEF)*, an energy generating floor for large scale applications (Box 6.8). SEF interacts with people walking on it and communicates a sustainable message linked to a brand. Therefore, the third phase of Sustainable Dance Club is characterized by interactions with potential customers and a series of design experiments (Figure 6.28).

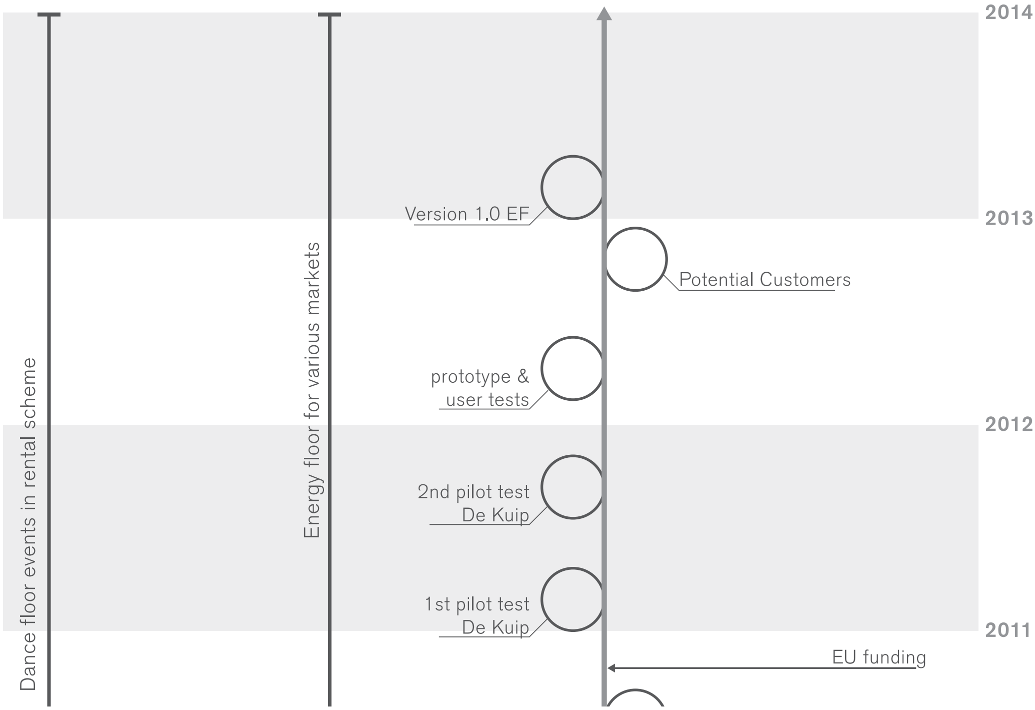


Figure 6.28. Design and stakeholder cycles throughout phase III

Although in the beginning of 2010, Sustainable Dance Club decided to focus on the development of the SEF, the firm did not have the necessary financial resources for R&D. The firm applied for an EU funding in early 2010, which was finally granted at the end of 2010. Through Enviu, Sustainable Dance Club came in contact with De Kuip, a soccer stadium in Rotterdam, which is an internationally well-known location. These developments led to pilot tests in 2011 in De Kuip that aimed at building an energy neutral stadium and the use of energy floor tiles.

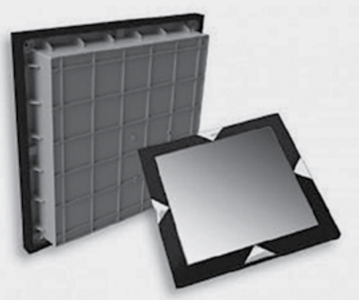
Box 6.8. Description of the SEF

The kinetic energy from walking or dancing is converted into electricity, which is used to make the floor react and interact visually as well as powering applications, which show the direct electricity output of a person's moves. The interactivity works as transmitter for the sustainable message of a brand, product, or a firm.

The SEF can convert footfall into electrical energy with an efficiency of 50%. Five watts per step can be produced by a small vertical movement. That means less effort is needed to create energy (walking is enough). This is the main difference in comparison to the dance floor. Moreover, the tiles are smaller (50*50 cm) and easier to install. The surface can be customized with light effect, logos, colors and materials.

Similar to SDF, SEF modules harvest human power and convert it into electrical energy. One step on the modules can generate between 2-10 joules depending on the weight of the user, the type of movement and the maximum deflation of the module. The center of the module can be made from different materials such as recycled ceramics, recycled rubber, synthetic materials, glass or bamboo. A strong but flexible rubber seal completely seals the module. It is designed to be waterproof for outdoor use. The housing is made from very strong stainless steel. Even when secured to the floor, the module can be opened from the top and can be removed for maintenance.

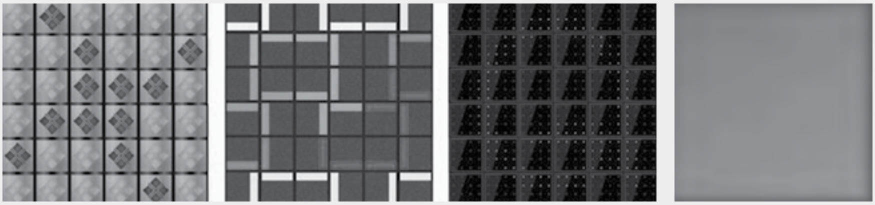
SEF integrated in the floor



SEF views

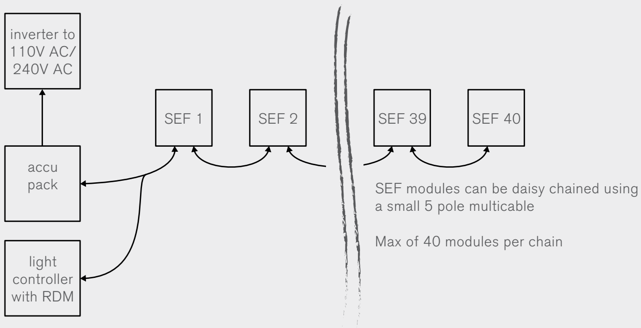
The design of the center can be customized further. The colored elements can light up as a form of interaction whenever someone steps on the module. Different set ups and designs are possible, as well as different ways to light up the module or external LED panels (slowly, intense, fading, etc.). Logo's can be printed or made visible with the LED lights.

Box 6.8. Description of the SEF (continued)



Examples of custom interactive top layers (using LED patterns) with tiles in a grid (except the last one; this is a single unit with a glass or synthetic top)

There are two cables for easy daisy chaining of multiple modules. The SEF modules, when regularly maintained, have an expected lifetime of 15 years minimum.



Schematic overview of a SEF installation

Pilot tests in De Kuip

In March and October 2011, two tentative tests were held. The aim of the test in March was to decide upon the ideal positioning of the SEF tiles, and whether the tiles should outstand or not. The test was performed in the Maashal, one of the two main entrances of the football stadium De Kuip in Rotterdam. The Maashal has the biggest and most continuous stream of visitors. Figure 6.29 shows the test setup.

In this initial test, the tiles were simulated by using pressure sensors and made visible by way of a lanbox and a computer. Four different floor settings (Figure 6.30) were used with tiles of 40*40 cm: 1) a smooth surface with spread underneath 8 pressure sensors, 2) a surface with an outstanding carpet with a block of 2x4 pressure sensors underneath, 3) a smooth surface with a block of 2x4 pressure sensors underneath, and 4) a surface with 8 outstanding surfaces each with pressure sensors underneath.

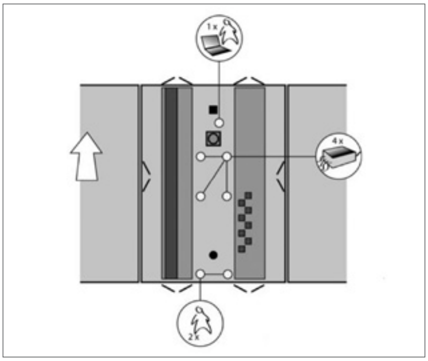


Figure 6.29. Test setup

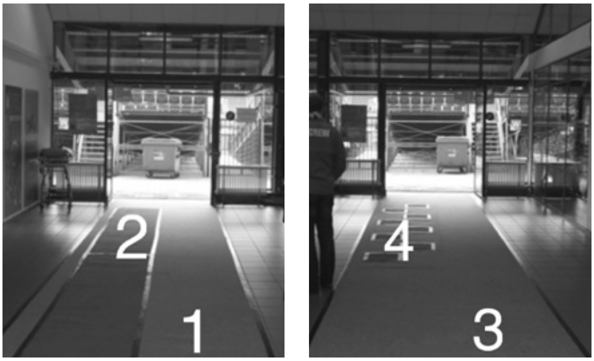


Figure 6.30. Floor settings used during the test

Three researchers were present during the test. One researcher had a laptop and counted the number of passengers. The other two researchers were at the entrance and observed walking patterns and collected qualitative information.

The results of this first test showed that the outstanding surface (floor number 4) attracted more attention than the other floor settings because it was more recognizable as a tile. Therefore, the team concluded that a floor surface with striking tiles would stimulate people to walk on it. It was also concluded that people responded to feedback when walking on the tiles, i.e. a direct feedback would encourage them to walk on the tiles. These results led to a subsequent test in October 2011 in order to further research the walking pattern of people, and evaluate the functional impact of SEF modules as well as its interaction with and appreciation by the pedestrians.

The second test was constructed in such a way as to get confirmation on the following hypothesis: A direct feedback would raise attention for the SEF modules; thereby a person will be more inclined to walk on the modules. Furthermore, the feedback also increases attention for the related information board (in this case an advertisement for an imaginary orange brand ‘Mandarina’).

The test setup involved two paths of eight outstanding tiles (Figure 6.31). One path was linked to a poster and an LED lamp for a light signal, and the other to a poster and a speaker for a sound signal (Figure 6.32). A camera was used to record the walking patterns of people and the possible connection with the feedback given in the form of light and sound. The test aimed to explore how people liked the tiles and the links between the footsteps of people and the feedback, as well as the tiles and posters of the advertisement.

The following observations and measurements were taken: 1) video registration to visually determine a possible relation between feedback and the behavior of the pedestrians, 2) a questionnaire was filled out by randomly chosen pedestrians (about 100), and 3) a digital log kept track of how many people, and with what kind of frequency walked on the SEF modules.

Conclusions from this second tests were as follows. Besides exceptions, it became immediately apparent that the pedestrians had a lack of interest in the SEF modules. Their focus was primarily on their tickets, getting something to drink/eat and/or getting to their seats (more and more so as the start of the football match came closer). Some people did notice the sound but did not relate it to the floor and looked around bewildered to find out where it came from, whereas visitors of the floor with the light interaction had expected a sound as feedback. In summary, the pedestrians perceived the feedback (i.e. a flickering light on one site and some tunes from a musical accord on the other site), but did not correlate it with their steps on the tiles.

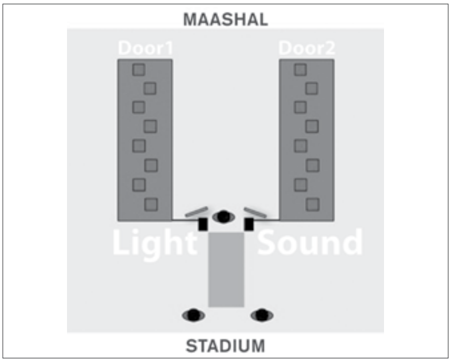


Figure 6.31. Test setup of the second test

Figure 6.32. Light-poster installation and sound-poster installation

Moreover, the visitors did not understand that the information board was related to the feedback seen/heard. The interviews with the pedestrians confirmed these visual observations. The absence of clear context of the floor, its feedback and the presented information was possibly to blame for this. For instance, the firm assumed that if the SEF modules were marked with a Feyenoord logo and the sound feedback were segments from the club song or together with a favorite player from the home team holding the related beer brand (e.g. Amstel) presented on the information board, the outcome would be very different.

Initial prototype of the SEF and subsequent tests at TU Delft

Based upon the firm's technology and the results of pilot tests in 2011, an initial prototype of SEF, a set of five modules, was built. In April 2012, two tests were conducted at TU Delft that would allow a better understanding of how to capture the attention of potential users and their reactions. One of those tests was particularly focused on the application of the SEF in the retail environment.

The first test was conducted at IDE, at a very visible spot near the entrance. The second test was conducted during the event 'New Retail Symposium', at Congress Center of TU Delft. The SEF prototype was located in the foyer of the event. The setting of both tests consisted of two tiles of SEF prototype on a white platform (Figure 6.33), accompanied by a screen that allowed users to see the energy that was produced during the use, together with a small retro-illuminated advertising board that was powered by the generated electricity.

Figure 6.33. Setting of the first test (left) and second test (right)

A questionnaire was developed in order to gain direct feedback from users regarding their perception of comfort and additional information in the form of an energy meter and product features. Furthermore, tests were video recorded to complement the direct observations during the tests.

Overall, tests of the SEF prototypes showed that people appreciate actively participating in energy production. Over 50% of the participants were pleasantly surprised and satisfied and over 20% were interested in the product. More than 77% were excited about the production of one's own energy. Furthermore, the features that make the product most appealing were reported as interaction, light, sound and the use of colors. Among others, retail environment, traffic areas, sports/fitness were the most mentioned potential application areas for the SEF. Moreover, some usability problems were reported as well; the rigidity of the tiles increased the required pressure and testers had to step on the tiles more aggressively in order to produce electricity.

In parallel to development and tests, Sustainable Dance Club was in contact with a number of potential customers from various markets such as construction, carpet, video equipment and entertainment, railways and advertising. Therefore, an early version of SEF (8 tiles) was released in May 2013 for testing and demonstration projects with potential clients. During this time, Sustainable Dance Club received two governmental subsidies in 2013 for demonstration projects in Brazil and India.

Outcome of Phase III

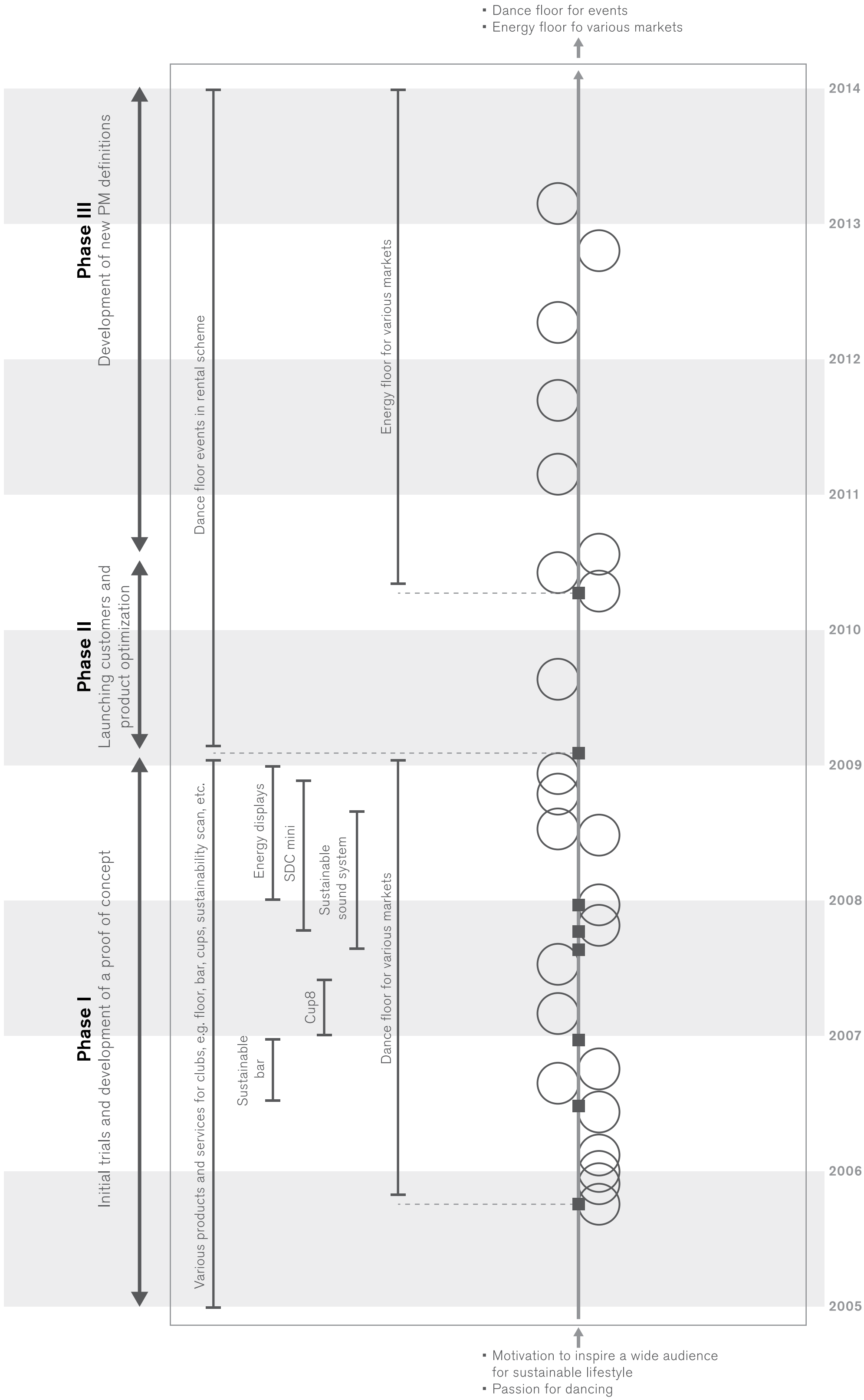
Since the end of 2010, Sustainable Dance Club has been involved in two main activities in a number of selected markets: marketing and sales/rental, as well as the development of the SEF. Throughout 2011 and 2013, a number of tests were carried out to develop a proof of concept and an early version of SEF. The interactions of Sustainable Dance Club with various potential customers led to two contracts. One of these was with the Russian railways for the development of new products that can be implemented on a large scale for public and industrial locations (e.g. in platforms and railway stations). The other contract is with a construction firm, which is interested in exploring the use of SEF in large buildings. Sustainable Dance Club aims to co-develop the business model and SEF together with those customers signing deals. Other potential markets and applications could be concerts and events, a computer floor, and the use of floor in combination with billboards and street furniture in public spaces such as bus shelters or airports.

Currently, Sustainable Dance Club is in contact with a number of potential clients who expect lower prices for permanent installations (e.g. sales). Therefore, the aim of the firm is cost reduction and development of complementary products in order to keep existing clients and convert the potential clients into business. The complementary products such as energy display or charger (i.e. any product connected to the floor) are selected and designed based on the feedback of the customers.

6.2.5. Conclusions Sustainable Dance Club case

As illustrated in Figure 6.34, the innovation process of Sustainable Dance Club consists of three phases. The first phase is characterized by a number of product iterations with a focus on the clubbing market. In this phase, a series of short-term affordable experiments were conducted in order to evaluate the reaction of various stakeholders. An initial prototype of the dance floor was built; however, the technicalities of the design were not worked out in detail. This prototype can be considered as an initial exploration to the possible technologies, dancing experience as well as the potential demand within the market. Furthermore, in this phase, Sustainable Dance Club was founded and the decision to focus on the development of the dance floor as the flagship product of the firm was made. This led to the development of the first series of the SDF, which was used at a number of events with paying customers. This phase ends with canceled orders and a shift in the business model from sales to rental. In the second phase, Sustainable Dance Club put its efforts mainly into the development and optimization of the subsequent SDF series (version 1.0 and 1.1), i.e. the two separate layers were integrated, resulting in a more industrial product. Since their production, these two versions have been sold and rented to various organizations, which accounts for the main income of the firm. In the current and last phase of the innovation process, the firm has been focusing on the development of a new application targeting a number of markets. This phase consists of a number of pilot tests and the development of an initial prototype and an early version of SEF. In parallel to the research and development, the firm has been focusing on marketing and growth through sales and rental of the SDF. Table 6.2 gives an overview of Sustainable Dance Club's iterations.

Figure 6.34. Overview of Sustainable Dance Club's innovation process: phases and iterations ››



▪ Dance floor for events
▪ Energy floor fo various markets
Phase III
Development of new PM definitions
Phase II
Launching customers and product optimization
Phase I
Initial trials and development of a proof of concept
Dance floor events in rental scheme
Energy floor for various markets
Various products and services for clubs, e.g. floor, bar, cups, sustainability scan, etc.
Energy displays
SDC mini
Sustainable sound system
Cup8
Sustainable bar
Dance floor for various markets
2014
2013
2012
2011
2010
2009
2008
2007
2006
2005
▪ Motivation to inspire a wide audience for sustainable lifestyle
▪ Passion for dancing

Table 6.2. Overview of Sustainable Dance Club's iterations

Phase	Iteration #	Period	PM definition
1	Initial PM	2005 – 2009	A portfolio of products for clubs (various product concepts)
	1	2006	Dance floor for clubs in a sales model
2	2	2009 – 2010	Dance floor for events in a rental scheme
3	3	2010 – 2014	Energy floor as a large scale application for public spaces

Definition of initial PM combination

Sustainable Dance Club started with the ambition of making the entertainment industry more sustainable, particularly clubs and events, through a variety of products and services. When the project started, there was not a specific product idea but instead a market in which Enviu and Döll aimed to make more sustainable. As such, the firm engaged in a number of product concepts for the clubbing market. Therefore, the selection of a specific market appears to be explained by the motivation of the firm's founder, who did not have previous experience in the clubbing market and energy conversion technologies.

Decision on initial actions

The initial action of the project team was to engage in a number of stakeholder interactions in order to find partners and potential customers who would be interested in further developing the product ideas. Subsequently, a series of short-term affordable design experiments were conducted for various product ideas that could make a club more sustainable. The expertise of the entrepreneur appears to explain the initial focus on stakeholders and subsequent short-term affordable design experiments.

Consequence of actions and subsequent PM iterations

Focus on the development of the floor (iteration #1)
Throughout 2005, Sustainable Dance Club conceptually developed and promoted a number of ideas that could make the clubs more sustainable. The energy generating dance floor is one example. Others include capturing the sweat of dancing people to flush toilets, energy saving measures like smart acoustics, and LED lightening systems. At the end of 2006, the team decided to put their development efforts mainly on the dance floor idea. Focus on the dance floor can be explained by the enormous attention the dance floor idea received. Various organizations were interested in placing an order once the floor was developed and ready.

Shift to the rental model and various market segments (iteration #2)
The shift from a sales model to a rental model appears to be influenced by the mixed outcome of design experiments, as well as the negative feedback from potential customers within the target segment, which appears to be influenced by the financial crises in 2008. Firstly, the team realized that powering the clubs' lighting system even partly through the dance floor was technically not feasible, at least in the short term. The amount of electricity produced through dancing was not as high as expected. As a result, the team decided to develop the dance floor and integrate sustainability in such a way that a message could be conveyed to young people, inspiring them to lead a sustainable lifestyle. The idea of creating awareness was still fitting to Sustainable Dance Club's initial sustainability vision and therefore, the firm shifted its focus more on the promotional value of the floor and its interactive aspects. Secondly, throughout 2008, there were many organizations, mainly drink brands, which were interested in placing an order once the floor was finished. There were a few big deals waiting on the pipeline, which could enable Sustainable Dance Club to kick-start the business. For instance, Absolut Vodka was partly financing the development of the first floor (version 0.1), and was interested in subsequently buying the floor. Despite these exciting developments, many interested parties could not finance an SDF when the financial crises of 2008 hit. Furthermore, during their interactions with clubs, the team realized that the dance floor was not financially viable for many clubs as a long-term investment. As a result, Sustainable Dance Club's focus shifted from a sales model to a rental model and away from clubs to various segments with a focus more on the promotional value of the floor and its interactive aspects.

From the dance floor to the energy floor (iteration #3)
As the effects of the financial crises were diminishing throughout 2009 and 2010, Sustainable Dance Club aimed at shifting from a reactive survival mode to a more active mode in order to capture the value of its patented technology and promote sustainability in other market segments. Meanwhile, since its foundation, the firm was getting more requests for different types of floors. After a yearlong process, the firm was granted an EU funding at the end of 2010. Therefore, the decision to develop a new application can be explained by the resources that became available during the process and commercial and environmental goals of the firm, i.e. capturing the value of the technology and promoting sustainability based on the feedback from a number of potential customers.

6.3. CASE: EVENING BREEZE

The main interviews for the Evening Breeze case were conducted with Thomas van den Groenendaal (CEO) and Yoeri Nagtegaal (Product Development Director). The interviews took place in August 2010, July 2012 and October 2013. The documents related to lab tests and prototypes, as well as Masters theses and the firm's website provided complementary data.

Evening Breeze was selected as a case for its focused PM development process that involved moderate levels of technical uncertainty. The initial phase of Evening Breeze's product development process consisted of lab and field trials with immature versions in an effort to develop a proof of concept of an air conditioning bed for the hospitality market, particularly tropical eco-resorts. Subsequent phases of Evening Breeze consist of production trials, as well as development of new applications for the high-end consumer and hospitality markets.

6.3.1. Introduction to the firm

Evening Breeze was established in 2006 by two former IDE students, Thomas van den Groenendaal and Yoeri Nagtegaal, as well as two eco-tourism experts Tim van den Brink and Nico Visser. Evening Breeze was founded with the vision of making the tourism sector more sustainable with a focus on energy use within the eco-resorts. The firm had been developing an alternative to conventional air conditioning for tropical resorts after dealing with high energy prices, high overnight temperatures and the presence of insect based diseases. Evening Breeze offers air-conditioned bed systems that significantly reduce the cooled space and cooling time by focusing on the bed and night. Evening Breeze's slogan illustrates this ambition: "cool dreams for a better planet". The target market was initially selected as the hospitality market in tropics due to the high saving potential linked to the climate throughout the year. Currently, the firm offers solutions for the consumer market as well.

Summary of the evolution of the product concept

Evening Breeze's PM definition has been evolving smoothly and involved two major iterations. The ambition to develop a sustainable alternative to the conventional air conditioning led to the development of a product for a niche market (i.e. the hospitality market). It was called *Evening Breeze four-poster* cooling system. The product idea was to develop an air-conditioned four-poster bed that only cools the bed space providing economic benefits to the resorts. Furthermore, the firm aimed at developing custom-made beds for the resorts who buy the air-conditioning system. After the successful results of the pilot tests and positive feedback both from the hospitality and high-end consumer market, the focus of the firm shifted mainly to the Dutch consumer market because of proximity reasons. This led to a new application called *Evening Breeze stand-alone*, allowing customers to keep their existing bed. Subsequently, the firm developed a new version of the four-poster bed based on what they had learned from the stand-alone version. Moreover, the firm's focus has been shifting towards the hospitality market again due to a decline in the retail sector. Based on the feedback from the resorts, Evening Breeze developed a new version, called *Evening Breeze suspended,* throughout 2012. These three models constitute the current product portfolio of the firm.

Technology description

Figure 6.35 shows two alternative embodiments of the Evening Breeze air conditioning system. It comprises of a cooling unit (3) for generating cooled airflow; and an air duct for guiding the cooled airflow from the cooling unit to a location (2) for cooling. The cooling unit has a suction mouthpiece (5) and an outlet mouthpiece (6). Via the suction mouthpiece the cooling unit draws in air from the location (2) for cooling in the direction of arrow D. The indrawn air is then cooled by means of the cooling unit and blown out via an outlet mouthpiece as a cooled airflow into the air duct (7). The air duct guides the cooled airflow to the location (2) for cooling. The whole wall (8) of the guide-duct is permeable to the airflow so that cooled air flows substantially everywhere on the wall of the guide-duct. The outflow part (8a) of the wall placed above the location for cooling has higher air permeability than the guide part (8b) of the wall. This way, the cooled air flows out mainly via the outflow part of the wall, which then moves downward in the direction of arrow C to the location for cooling (Nagtegaal, Van den Groenendaal, & Jansen, 2011).

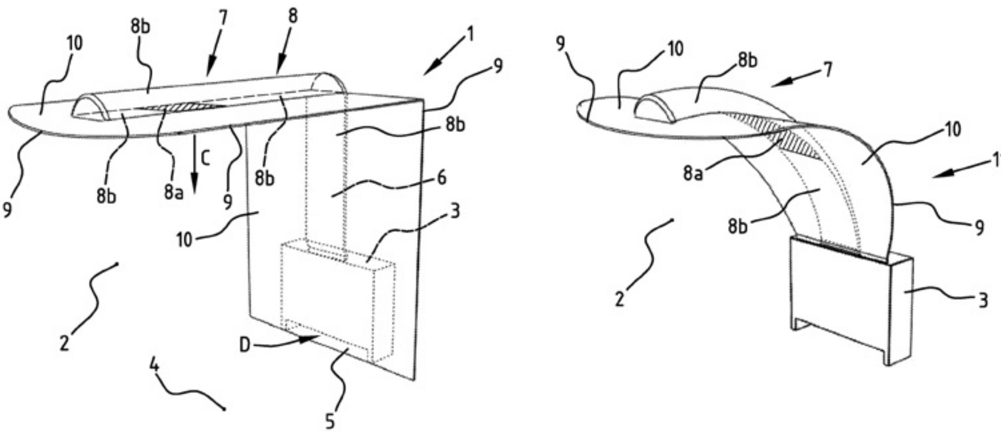


Figure 6.35. Alternative embodiments of Evening Breeze air conditioning system

Team composition

Before the firm was founded between 2001-2006, the project was managed by two ecotourism experts, Tim van den Brink and Nico Visser, who at the same time had initiated the idea. Van den Brink and Visser had several years of experience in ecotourism and collaborated in several eco-room projects for tropical resorts. They had a conceptual idea and possessed market knowledge, including a wide network. In 2006, two former IDE students, Thomas van den Groenendaal and Yoeri Nagtegaal, have been involved and managed the activities since then. While Van den Groenendaal has been involved in all commercial and operational matters, Nagtegaal has led the product development activities, e.g. development of first prototypes and production series of the Evening Breeze cooling system. The team was supported by Van den Brink and Visser who provided their expert knowledge and local network in the tropics, although, their involvement has gradually decreased since 2009. Since the firm was founded in 2006, its size has fluctuated around 5 employees. Throughout 2008, an industrial design master student was included in the team for the design and development of the stand-alone version of Evening Breeze. In 2012, a sales manager was contracted with a focus on the tropical resorts. As of 2012, a new managing director was involved in the team by purchasing an ownership stake in the firm. In addition, throughout the whole process a number of industrial design students and interns were involved with diverse activities, such as market research, development of launch strategies and sales.

Sustainability motivation of the team

Since the emergence of the idea in 2001, Evening Breeze has pursued both environmental and financial goals. The idea of reducing energy consumption in resorts by limiting the cooled space was perceived to be a win-win situation, as it provided economic benefits to the potential clients. However, with the difficulty of reaching resorts in the tropics, and generating a higher volume of sales, between 2008 and 2011 the firm shifted its focus to the consumer market in the Netherlands. In the Netherlands, the environmental benefits of the concept were significantly lower compared to hospitality market (considering the number of days per year the product is being used in addition to the chance of selling a luxury product to consumers who did not own an air-conditioner). Apparently, short-term revenue generation in order to secure firm survival was perceived to be crucial in this period, and although the hospitality market was never abandoned, the financial goals were prioritized over environmental goals in this period.

Business model

Evening Breeze currently targets two distinct markets: hospitality and consumer markets. The firm reaches the hospitality market through direct interaction with resorts and in some cases through collaboration with Kiwinet; a South African based mosquito net manufacturer, who offers Evening Breeze cooling systems to their own clients. The firm also reaches private consumers through bed manufacturers and their retail shops. During the second half of 2013, the firm put its efforts in searching for partners to develop a new application for hospitals.

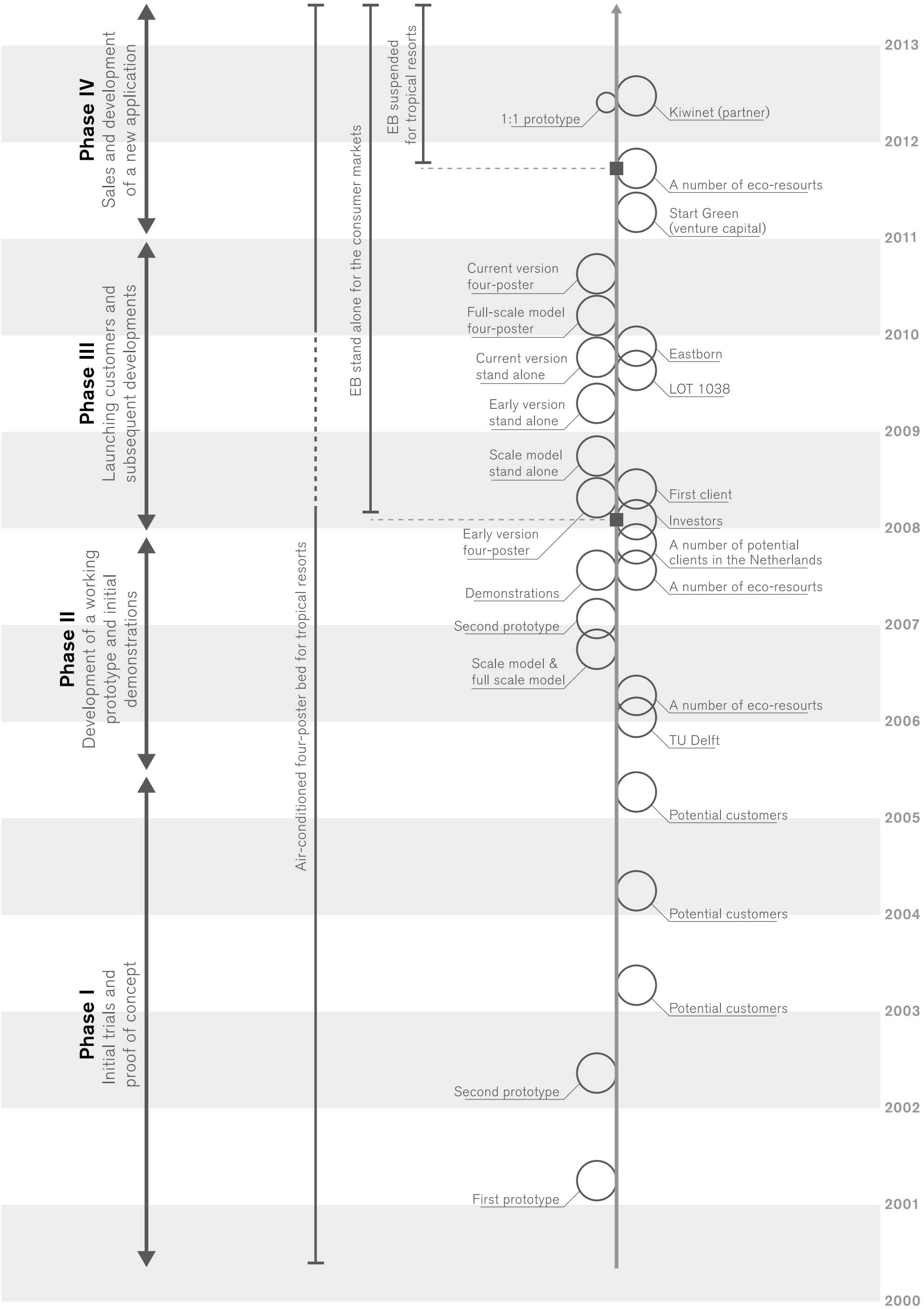
Financial resources

Thomas van den Groenendaal and Yoeri Nagtegaal; the two former IDE students who founded Evening Breeze had scarce resources. The initial prototypes were built in collaboration with suppliers who provided the cooling unit and ventilation system free of charge. Furthermore, the founders of the idea, Tim van den Brink and Nico Visser, partly supported the development from a financial, knowledge and network point of view. Subsequent prototypes and demonstration projects were mainly financed by competitions won during 2007 and 2008. Throughout 2008 and 2009, Evening Breeze was busy with the development of production models for two different applications (namely a four-poster bed and a stand-alone model). These developments were mainly financed by the initial investors of the firm. Since 2009, the firm puts its efforts primarily on sales within the consumer market and since 2011 on the hospitality market. In 2010, their main revenues were gained through the sales in the consumer market and between 2011-2013 from the hospitality market. The firm became independent in 2008 and the break even was achieved in 2010.

Overview of PM iterations, design experiments and stakeholder interactions

An historic account of Evening Breeze's innovation process is illustrated in Figure 6.36. Iterations of Evening Breeze are categorized into four phases. The beginning of the first phase between 2001 and 2005 is characterized by initial prototypes in an effort to explore the feasibility of an air-conditioned bed. After these prototypes, the project went into a period of stagnation until involvement of Van den Groenendaal and Naagtegaal. The second phase between 2005 and 2008 is characterized by the development of a working prototype and a subsequent demonstration project with the aim of testing the system in a real situation with actual users. Evening Breeze's third phase consists of launching customers and a number of subsequent application developments. Two of these developments happened in China in order to setup the production of the applications: Evening Breeze four-poster and Evening Breeze stand-alone. The fourth and current phase of the process is characterized by sales to the hospitality market and the development of a new application called Evening Breeze suspended.

In the following paragraphs, each phase will be explained through a detailed description of the PM combinations and an overview of actions, in terms of stakeholder cycles and design cycles. The PM combinations, stakeholder and design cycles are determined by their centrality in interviews as well as complementary documents.


Phase IV
Sales and development of a new application
Phase III
Launching customers and subsequent developments
Phase II
Development of a working prototype and initial demonstrations
Phase I
Initial trials and proof of concept
Air-conditioned four-poster bed for tropical resorts
EB stand alone for the consumer markets
EB suspended for tropical resorts
1:1 prototype
Kiwinet (partner)
A number of eco-resourts
Start Green (venture capital)
Current version four-poster
Full-scale model four-poster
Current version stand alone
Early version stand alone
Scale model stand alone
Early version four-poster
Demonstrations
Second prototype
Scale model & full scale model
Eastborn
LOT 1038
First client
Investors
A number of potential clients in the Netherlands
A number of eco-resourts
A number of eco-resourts
TU Delft
Potential customers
Potential customers
Potential customers
Second prototype
First prototype
2013
2012
2011
2010
2009
2008
2007
2006
2005
2004
2003
2002
2001
2000

6.3.2. Phase I: Initial trials and development of a proof of concept

When evening Breeze was founded Tim van den Brink was running an eco-consultancy firm in Curacao, and Visser was both a professor in Sustainable Toursim at a Dutch university and the head of the department of Public Health and Environmental Hygiene in the Netherlands Antilles government. They had previously collaborated on several eco-room projects for tropical resorts and together with other environmental experts, they determined that air conditioning accounts for 80% of energy use in tropical hotel rooms causing high energy bills for resort management. Moreover, it contributed to local and environmental damage.

A number of alternative applications existed at the time such as passive cooling established by fans or shutters, add-on products such as sensors, time clocks and smart cards, as well as energy efficient central systems involving high investments. None of these applications appeared to be truly satisfactory.

The team had established that since most tourists spend their time outdoors during the day, passive cooling with a fan was enough during this time. The air conditioning was only necessary during the night, and exclusively cooling the bed space with an air conditioner would satisfy the cooling demand of the guests. In order to explore the feasibility of this idea, they built two prototypes in 2001 and 2002 (Figure 6.37). The concept was called *ice cube bed*.

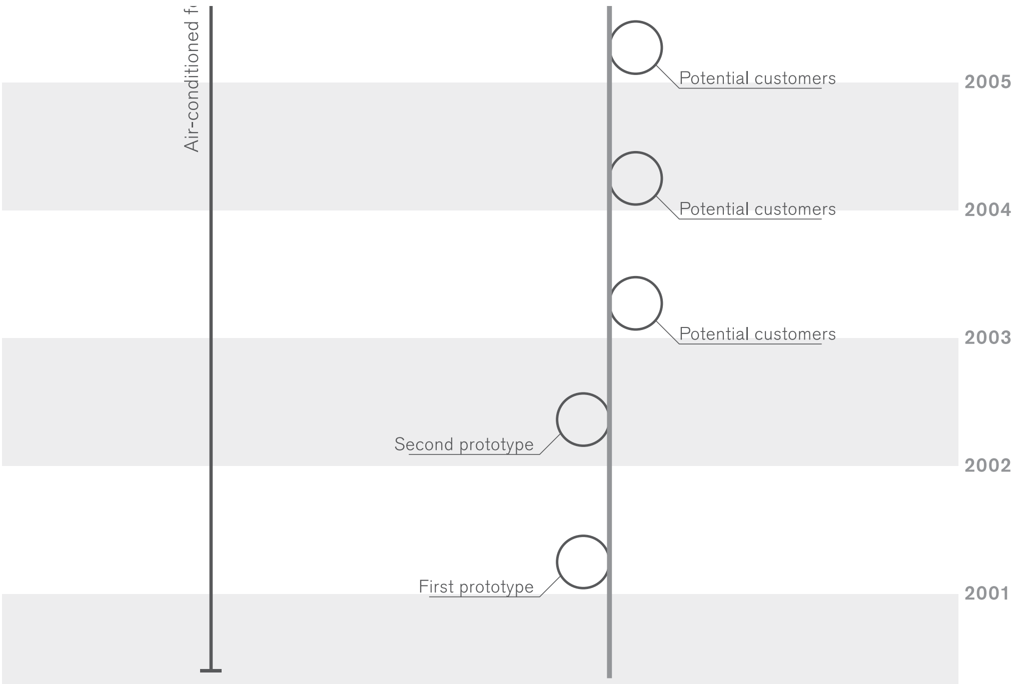


Figure 6.37. Initial actions in phase I

« *Figure 6.36. Overview of Evening Breeze's innovation process: phases and iterations*

Initial prototypes

The first prototype of the ice cube bed was built in 2001, and was isolated from the bedroom by a fabric cover (Figure 6.38). The air conditioner was placed inside this closed sleeping space. As a first prototype a queen size bed was tested. The bed was provided with a PVC frame draped with cotton. Windows in the transparent cotton prevented users of the bed to become claustrophobic. The cotton layers were closed by Velcro; a fabric hook-and-loop fastener. Results showed a considerable decrease in energy consumption for cooling; however, this prototype of the ice cube bed was not considered to be aesthetically appealing or comfortable enough to be placed in a hotel guest room.

A second prototype of the ice cube bed was built in 2002, this time using a canopy bed draped with a light, curtain-like cotton (Figure 6.39). In this prototype, Velcro closings were not used as it was a nuisance when people had to leave the bed during the night. Instead the drapes overlapped, creating a natural closing, which was easily opened, but still had the ability to keep most of the cooled air inside.

Figure 6.38. First prototype of the ice cube bed

Figure 6.39. Second prototype of the ice cube bed

A 9000 BTU* through the wall unit was used to test the bed for a period of 3 weeks. During this period, the following variables were recorded: temperature in the bed and the room, humidity in the bed and the room and the power (kWh) used by the air conditioner. The results from this test were promising. The effective cooling time from 30°C down to 26°C was 5 to 10 minutes, compared to an hour using a regular air-conditioner.

A surprising observation was the rise in relative humidity produced by two people through respiration and perspiration while they were sleeping. A typical side effect of using compressive air conditioning is a decrease in humidity; however, this changed when a relatively small sleeping space was cooled. While the comfort zone for relative humidity lies between 25 and

** Most air conditioners have their capacity rated in British thermal units (BTU). A BTU is the amount of heat required to raise the temperature of one pound (0.45 kg) of water 1 degree Fahrenheit (0.56 degrees Celsius). In heating and cooling terms, 1 ton equals 12,000 BTU.*

60%, the humidity experienced by the experimental subjects during the test was between 70 and 80%. This was described as a welcome side effect; test subjects stated that they were *"not so thirsty at night"* and had *"less irritation of their eyes and nose"*.

Furthermore, the average energy savings per night were approximately 55%, with a drop from 0.94 kWh to 0.43 kWh. The test was done in a relatively small bedroom of 5 x 4.5 m compared to a typical hotel room, where an energy use of 2 kWh per hour is considered to be normal.

Outcome of Phase I

After the initial prototypes and tests, the speed of the project declined. Nevertheless, its ambassadors Tim van den Brink and Nico Visser kept posing the concept in many resorts they visited during their own professional activities. The enthusiastic reactions from the market convinced them of the potential of the concept.

6.3.3. Phase II: Development of a working prototype and initial demonstrations

In the summer of 2005, Nico Visser came into in contact with Thomas van den Groenedaal and Yoeri Nagtegaal through his personal network. This potential design duo would bring their design skills and their connections within the TU Delft into the project. Van den Brink and Visser had a conceptual idea and market knowledge, including a wide network. These developments essentially led to the foundation of the firm in early 2006. Figure 6.40 gives an overview of actions taken during phase II

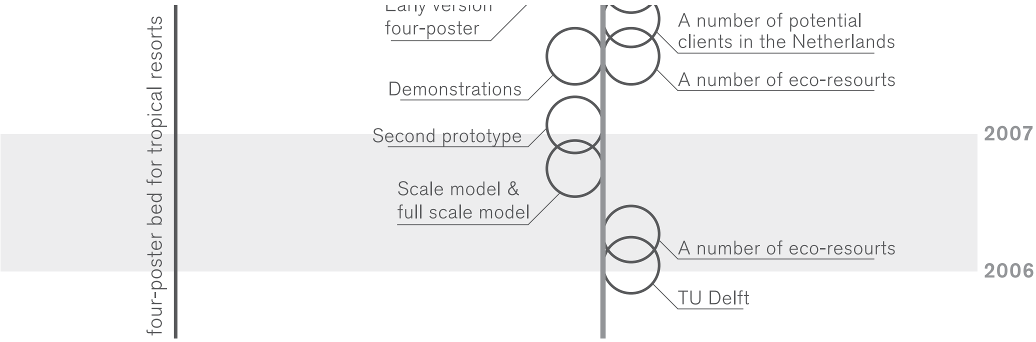


Figure 6.40. Design and stakeholder cycles throughout phase II

As soon as the firm was founded, Van den Groenendaal focused on the market feasibility of the concept and the development of a business and marketing plan. In 2006, Evening Breeze established contacts with potential customers within the eco-tourism market in order to receive input for the proposition and design of the *AircoBed*, which was the name of the initial concept. The AircoBed principle was presented to multiple resorts in the target market. The presentation consisted of a mailed leaflet or a real life presentation. Some resorts signed a non-binding letter of intent, in which the resort confirmed its interest in implementing the AircoBed, as long as it would live up to what was promised. Other resorts offered to cooperate in pilot tests with an AircoBed prototype.

In parallel, Nagtegaal focused on the design and development of a working prototype. Firstly, a scale model was built and tested in order to prove the principle of the AircoBed. Subsequently, a full-scale model was built and tested in order to calculate the necessary cooling capacity and determine the most suitable cooling technique.

The Scale Model Test (1:2.5)

The scale model consisted of an oblong steel frame with a wooden top, in which the sides were covered with a polyester fabric (Figure 6.41). Through the top of the construction, cool air generated by a 9000 BTU packed air conditioner was blown out. Eight sensors measured the temperature both inside and outside the model. The results showed significant insulating properties with a common polyester fabric, which also had a very high level of transparency. The difference between the temperature inside and outside the model was at least 3°C even close to the fabric. No measurement of energy use was done during these tests.

Full-scale test

The full-scale model was built with an aluminum frame that was covered with a polyester fabric (Figure 6.42). A split-unit 11000 BTU air conditioner blew cool air into the construction. The measurements done on this full-scale model also included energy use in addition to the eight thermocouples.

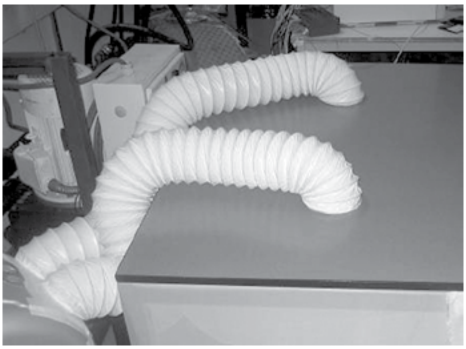


Figure 6.41. Tests with the 1:2.5 scale model

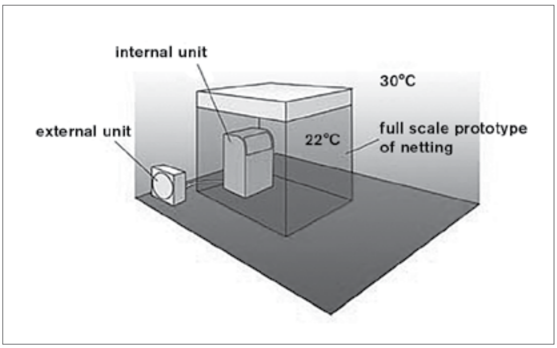


Figure 6.42. Test setup with the full-scale model

Test results demonstrated that outside temperature at one-meter distance from the bed and close to the floor was lower than close to the fabric and at a higher distance from the floor, since cool air descends due to its higher density. The team came to the conclusion that the fabric insulating the AircoBed should have a higher density close to the ground to trap the cold air. The insulation characteristics of the full-scale model were worse than the scale model, which was due to the higher outside temperature and the larger openings to enter and exit the AircoBed.

Furthermore, results showed that the energy used to cool the AircoBed to 22°C was 0.6 kWh per hour. This closely corresponded to the findings with the ice cube bed prototype, which used 0.46 kWh per hour and had much thicker fabrics.

Outcome of the scale-model and full-scale tests

Based on preceding prototype tests and calculations of the thermal load for the AircoBed, the team came to the conclusion that energy use of the AircoBed would be around 0.5 kWh per hour, and the capacity of the air conditioner required would range between 4600 and 5000 BTU.

Furthermore, during this period the team researched various conventional and new cooling technologies. Some important considerations during the search and selection process were initial investment costs, environmental friendliness, technical feasibly, noise and energy efficiency. Because of the short-term realization of the AircoBed concept as well as the technical feasibility of the cooling method, the team decided that the compression technology would be the most suitable cooling method for the AircoBed.

With regard to the insulation, common polyester fabrics were considered to have good insulating properties combined with good transparency. Moreover, in order to trap the descending cold air, the team decided to use a different type of fabric close to the ground, where transparency was not essential.

The working prototype

Based on the outcome of the preceding prototypes, a full-scale working prototype was developed early 2007. The layout of the cooling system is illustrated in Figure 6.43. In order to transport the cooled air from the cooling unit to the bed, a split-unit air conditioner was used, which is comprised of an indoor and outdoor unit linked by flexible piping. The split-unit was selected because of its silent operation and higher efficiency compared to other types of cooling units. Furthermore, in order to transport cooled air from the bed to the occupants, a textile based ventilation system was used, which uses textile ducts instead of metal ducts. A textile-based system ensures a uniform air distribution free of draught and noise. In late 2006, Evening Breeze came into contact with KE Fibertec, a firm that develops and manufactures ventilation and filtration systems based upon fiber technology. Evening Breeze and KE Fibertec agreed to collaborate in the prototyping phase free of charge.

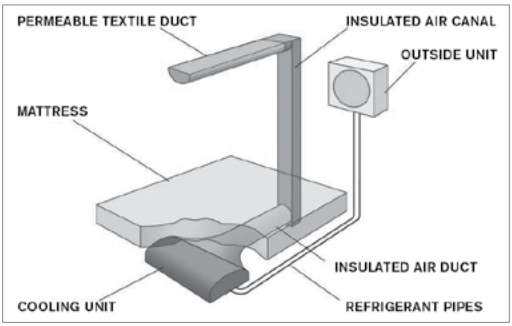
Within this initial version of the Evening Breeze cooling system, the interior unit was located underneath the bed and the air duct/canal was located behind the bed. In this way, the unit would be hidden and the bed mattress would absorb the sound of the unit.

A technical challenge during the development of the full-scale prototype was the selection of the cooling unit that fit the requirements of Evening Breeze. Considering the development time, costs and uncertainty of a tailor-made unit into account, the team decided to modify an existing unit and adopt it to the needs of the AircoBed. For this purpose, they started collaborating with Altena, who delivers cooling solutions for domestic and utility purposes. Altena agreed to cooperate in the development of the AircoBed prototype free of charge. The role of Altena was to develop a custom-made evaporator (indoor/cooling unit) based on the requirements of Evening Breeze, such as energy efficiency, sound level and comfort.

In addition to the technical challenges related to temperature, humidity and sound levels, the appearance and style of the prototype were important considerations. The team aimed to use the prototype for actual user tests and a makeshift bed with only technical functionality would have a negative influence on the perception of comfort. Apart from the purpose of testing, the prototype was expected to serve an exemplary function for resort and hotel managers, investors, and others. Consequently the team aimed to develop a bed with a contemporary look (Figure 6.44).

Tests with the working prototype

In order to asses the technical feasibility of the design and investigate how the cold air spread over the sleepers, the working prototype was tested in a climate chamber at TU Delft with several parameters such as the capacity of the air conditioner, energy efficiency, temperature within and outside of the bed, noise and others (Figure 6.45). Within the climate chamber, cylinders containing light bulbs were placed on the bed in order to represent people and the heat they created during their sleep. The temperature and humidity of the chamber was set to 30°C and 80% respectively, in order to simulate tropical climatic conditions.



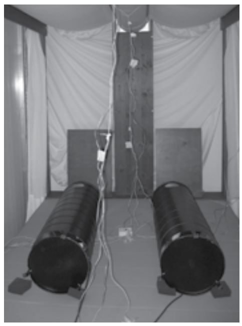


Figure 6.43. Cooling system layout of AircoBed (left)
Figure 6.44. Working prototype of AircoBed (middle)
Figure 6.45. Tests in the climate chamber (right)

Although the prototype proved to be successful, there were some issues with the setup of the test caused by the climate chamber. As soon as the air conditioning in the bed was turned on, the team realized that the climate chamber worked hard to compensate for the cooling and to increase the temperature, which is not the case in a real situation. In this case, the climate chamber was shut down and the test was continued. The prototype proved to successfully cool the bed space to the desired temperature. In order to increase the accuracy of the measurements, as well as test user comfort, the team decided to conduct a demonstration project with real users.

Demonstration projects

The tests in the climate chamber led to demonstration projects and the development of five units based on the working prototype. The firm installed demo beds in Kontiki Beach Club, Plaza Resort and Sorobon Beach Resort in Bonaire during September 2008, and subsequently at the Sefapane Lodge and Kololo Game Reserve in South Africa during November 2008; all of which were arranged through the network of Tim van den Brink and Nico Visser. The aim of the demonstration projects was to investigate the technical feasibility of the system in a real situation, as well as get the feedback of actual guests and resort owners.

The biggest technical issue the team encountered during the demonstrations was the condensate that was accumulating under the bed. The horizontal positioning of the cooling unit (see Figure 6.43 for the layout of the system) was making the discharge of the condensate difficult. This created a dangerous situation for the guest as the bed was using a 220-volt system with high amps. Normally, when the air conditioning system is on the wall, condensate falls into a dripping pan, which can be discharged through gravity with the rest of piping; however, because the cooling unit was on the ground, it was not possible to make use of gravity. During the field tests, a pump was used to discharge the condensate, which created noise and maintenance issues. Another issue was the accumulation of the condensate in the ventilation area above the sleeping space, which would drip on the sleepers when levels became too high.

Furthermore, the field tests enabled feedback of the actual guests who experienced sleeping in the bed to be collected. Reactions of the first users were very enthusiastic and provided input for the optimization phase. One unexpected result of the user tests was the complaint about the light in the rotation button at the end of the bed. This button allowed the user to set the system to low, medium or high. Guests were not happy about the light and complained that they could not sleep, as it was too bright. Such feedback was integrated into the design in the next design cycle.

6.3.4. Phase III: Launching customers and development of the series model

Evening Breeze had been in contact with investors since the onset of the project but was not able to convince them with a sketch of the product and the business plan. In the beginning of 2008 however, when they had just returned from South Africa, they won the prestigious

Shell LiveWIRE Young Business award with a prize of €10,000 (Figure 6.46). As Thomas van den Groenendaal explains, *"...we had beautiful pictures from the resorts in Bonaire and South Africa that the product was there and it looked really great. We had very positive references from the people sleeping there and the resort owners. We had the prize from Shell. So that was a package which was very positive"*. These developments led to both the first investors and first customer of Evening Breeze in 2008. Coral Lodge resort in Mozambique was interested in buying 10 units of the Evening Breeze system. During 2008, the firm focused its efforts on an early version in China. Figure 6.47 gives an overview of actions taken during phase III.

Figure 6.46. Evening Breeze won the Shell LiveWIRE Young Business award

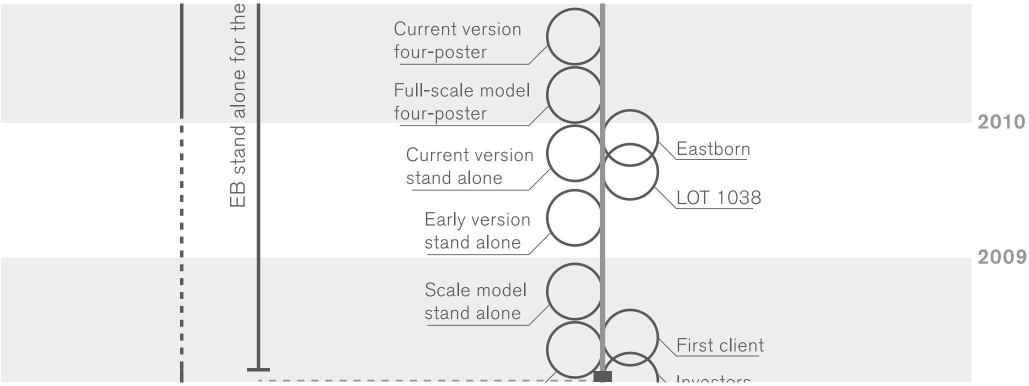


Figure 6.47. Design and stakeholder cycles throughout phase III

Development of early version of Evening Breeze four-poster

Yoeri Nagtegaal spent more than half a year in China in 2008 for the production of 15 units of the Evening Breeze system, particularly with a focus on the design and production of the cooling unit with Chinese AC manufacturers. They initially aimed to develop a cooling unit with all custom-made parts, but Chinese engineers were not used to this and had difficulties understanding the logic behind the system Evening Breeze wanted to develop. They were not accustomed to work from a paper design and needed a physical model to work with, which lengthened the development process. Furthermore, the Chinese way of AC manufacturing systems work seemed logical as Nagtegaal explains, *"I saw a lot more products there, I saw how they assembled them, I saw the logic behind it, and I thought we should change as well"*. These insights led to the design and development of a cooling unit that used many standard parts and made the system much cheaper. Furthermore, the horizontal design became vertical and made use of a drip pan, enabling the easy collection and discharge of the condensate. A standard housing was adapted in order to fit to the rigid air duct construction (Figure 6.48).

In parallel to the development of the production model in China, the first version of the remote controller (Figure 6.49) was developed which provided the user with different cooling modes such as cold, cool, fresh, breeze and gentle. The cooling ranged from gentle breeze to active cooling up to 7°C below the ambient temperature.

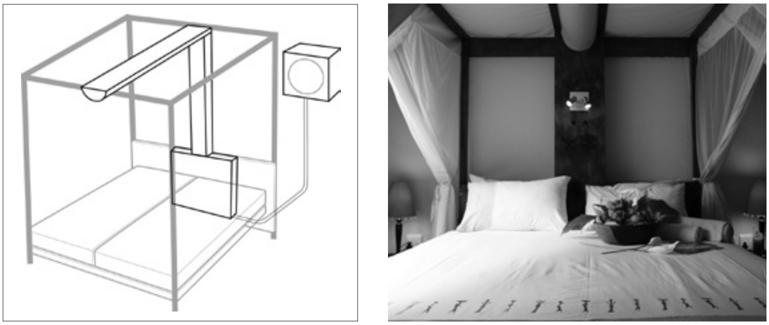


Figure 6.48. Design of version 0.1 (left) and its installation in Sefapane Lodge, South Africa (middle)
Figure 6.49. Remote controller of the system (right)

Meanwhile, as soon as the first investors were on board, the focus of Evening Breeze was shifting more towards the high-end consumer market. First of all, Evening Breeze was receiving attention from private consumers. Secondly, the firm aimed at expanding from the eco-chique niche market to the consumer market in order to get higher volumes of sales. Finally, the investors were interested in investigating the potential of Evening Breeze in the private sector with endorsement from a premium bed manufacturer and sold in retail stores. In the first quarter of 2008, a group of students conducted market research investigating the potential markets, and concluded that the South East of USA would have the highest potential due to both its size and humid climatic conditions. Therefore, in parallel to the development in China throughout the second half of 2008, an industrial design student from TU Delft conceptually designed the stand-alone version of the Evening Breeze system, which would allow customers to keep their existing bed. During the design process, the USA consumer market was taken as a case study and a questionnaire was posted in a number of online forums and answered by 62 American citizens from all climatic regions. The questionnaire gave insights into the acceptance and types of bedroom air-conditioning systems as well as the desirability of features for the stand-alone version.

Initial design and scale model of the stand-alone version

The main challenge of developing a stand-alone version of the Evening Breeze cooling system was to make it compatible with a high diversity of beds and bedrooms. Moreover, the team was not satisfied with the rigid air duct in the earlier version, which was increasing the environmental impact of transportation and shipping costs of the product. A preliminary concept of a stand-alone version (Figure 6.50) was designed to include a fabric canopy placed over the bed in order to make the product appear like it was part of the bed, while reducing the amount of materials and size of the rigid part of the air duct.

Figure 6.50. Preliminary concept of stand-alone version (left) and its alternative constructions (right)

The rigid air duct would be connected to the interior unit and mounted to a frame, which would function as a headboard hiding the interior unit and air duct (Figure 6.51). Moreover, the headboard would shape the canopy behind the bed.

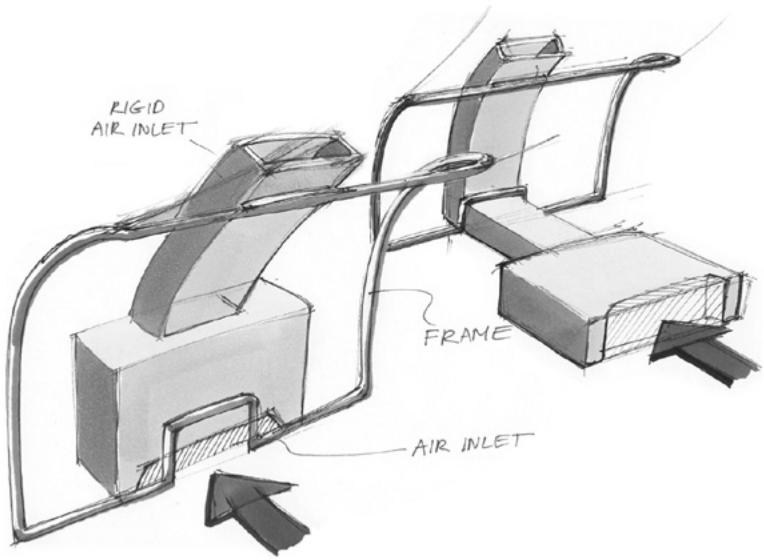


Figure 6.51. Construction of interior unit, head board and air duct in vertical and horizontal orientation

The fabric canopy would then be connected to the frame by means of Velcro loops and connected to the ceiling by wire. The textile air duct was positioned on top of the canopy to ensure a smooth appearance at the bottom side, which was the visible side for the bed occupant(s).

This concept was then communicated to the experts of KE Fibertec and Altena for an assessment of the air duct and canopy design for proper air distribution as well as the configuration of the interior unit (i.e. arrangement of the fan, evaporator and air inlet) for efficient air distribution and proper condensate discharge.

Expert consultation led to a scale model in order to investigate the feasibility of the design of the air duct and its construction (see Figure 6.52). The model proved that the frame and the counterweights allow a sturdy construction. Furthermore, the construction did not require any drilling. The frame connected to the interior unit shaped the canopy. The upper end of the canopy was pulled down by sand bags that functioned as counterweights.

Based on the expert consultation and scale model, a final concept was designed for the stand-alone version of Evening Breeze. In this concept, the air was blown directly into the textile air duct. Figure 6.53 shows conceptually how the air flows through the textile air duct, which would be connected to the air outlet of the interior unit. The fabric of the canopy was designed to be permeable in order to allow the air pass through the canopy. Similarly, the air duct was designed to be partly permeable in order to avoid condensate forming on the duct.

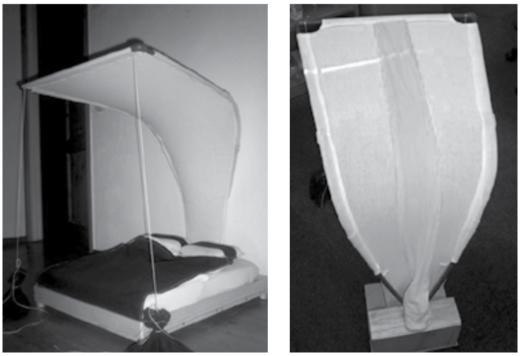


Figure 6.52. Scale model (1:3.5) of canopy, showing frame and counterweights and blue textile permeable air duct mounted on top

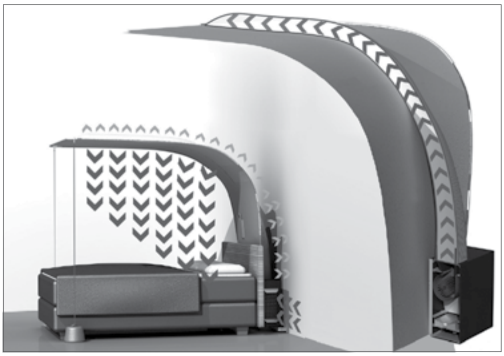


Figure 6.53. Textile guided air distribution and air flow through the textile air duct (right)

Furthermore, the configuration of the interior unit was conceptually designed in order to optimize energy efficiency, thermal comfort, noise reduction and the compatibility with a high diversity of beds. In this design cycle, the type and layout of the components, the direction of the airflow, condensate drainage, air filtering and noise reduction solutions were elaborated at a conceptual level.

Development of an early version of Evening Breeze Stand-alone and its launch

The scale model gave an idea about the shape and construction of the canopy; however, not so much about the technicalities of the product. In the next step, an early version was built in Delft from the components of the system developed in China. In this phase, a number of decisions were made concerning the materials based on their weight, flexibility, permeability and dimensions of the canopy. The team did not conduct an elaborate test with this working prototype other than structural tests for the construction of the frame and housing of the unit.

This working prototype was then launched at a fair in Curacao in September 2009. Subsequently, LOT1038, a high-end retail firm in Curacao, ordered five units of the stand-alone version in October. In parallel, during the second half of 2009, the firm went to China for a second time for the development of the current version of Evening Breeze stand-alone.

Development of Evening Breeze stand-alone in China

After the successful launch of the stand-alone version in Curacao in September 2009, a production model was developed in China at the end of 2009. In order to have an integrated system, the indoor unit was redesigned in such a way as to carry the frame of the canopy. The unit was similar to the cooling unit developed for the Evening Breeze four-poster bed in terms of the type and layout of the parts; however, it was improved in terms of the efficiency and weight, as well as the look, e.g. a new housing was designed. Furthermore, the ventilation system from KC Fibertec was too expensive for the Evening Breeze system, which led to the development of a new ventilation system without any rigid parts, i.e. the rigid air channel and textile air duct were integrated into one fabric. Figure 6.54 shows the design of the stand-alone version of Evening Breeze, which has had only minor changes since 2009.

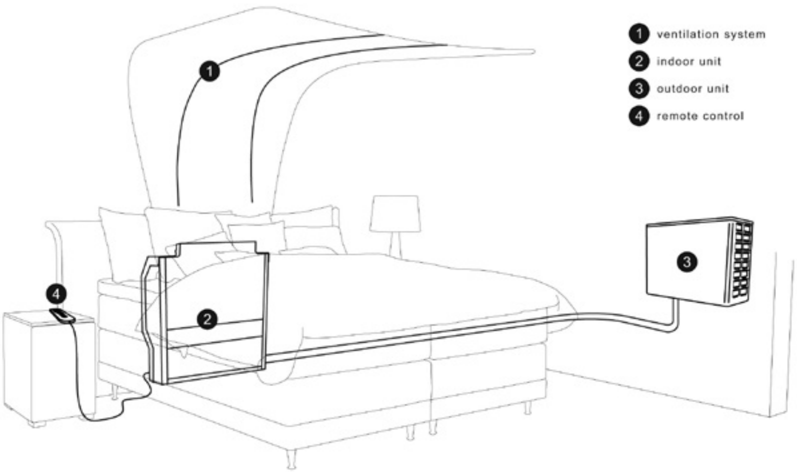


Figure 6.54. Design of stand-alone version

Launching customers

The stand-alone concept was receiving positive feedback from the Dutch consumer market and the team decided to expand its sales and marketing efforts in Europe, starting from the Netherlands. Evening Breeze had been in contact with a number of bed manufacturers during the second half of 2009, and eventually decided to collaborate with Eastborn; one of the biggest bed manufacturers in the Netherlands (Figure 6.55). In the beginning of 2010, Eastborn ordered the first batch of the stand-alone system.

Figure 6.55. Evening Breeze stand-alone system in collaboration with Eastborn

Development of the subsequent version of Evening Breeze four-poster

During the development of the stand-alone version, a new cooling unit had been developed with better energy efficiency, lower weight and a new housing. Another major change was the development of an integrated ventilation system. Although during phase III, the focus of Evening Breeze was the consumer market, the hospitality market was still on the agenda. During 2010, the team aimed to develop a new version of the four-poster system using insights gathered from the stand-alone version. Figure 6.56 illustrates the design of the latest version of four-poster system.

As a first step, the team built a full-scale model using the materials that they had used in the stand-alone version. This enabled a better idea of what the system should look like. Subsequently, they developed a manufacturing model together with the supplier in China.

The system was designed to fit on a standard 200*180 cm mattress, and required a head-box with a size of 180*30 cm in order to cover the cooling unit. The ventilation system fixtures were mounted on the bed at the marked areas as shown in Figure 6.57. Figure 6.58 shows examples of resort rooms and beds using the new version of Evening Breeze four-poster system.

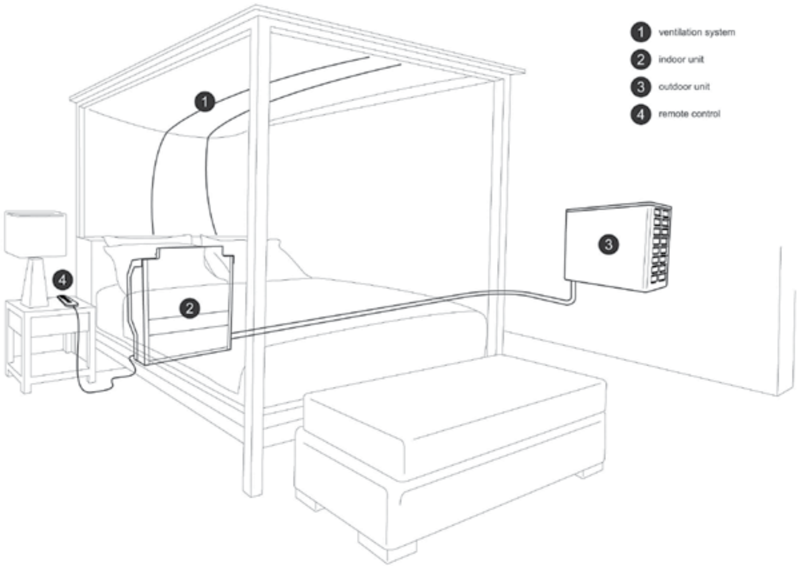


Figure 6.56. Design of the stand-alone version

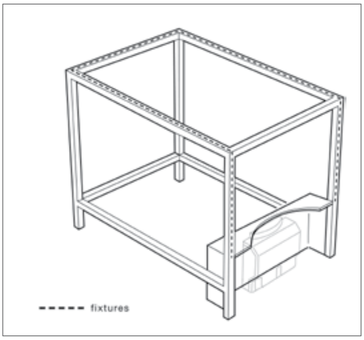


Figure 6.57. Installation of the system

Figure 6.58. Examples of installations using the new version of four-poster system

Outcome of Phase III

Phase III consisted of parallel and subsequent developments of four-poster and stand-alone systems, as well as launching consumers; both in hospitality and consumer markets. Nevertheless, from a target market perspective, the firm's focus had been on the consumer market, particularly since the involvement of the first investors of the firm. After the first sales in the Netherlands, the firm increased its efforts to expand to the warmer parts of the Europe such as in Spain and the south of France. Throughout 2010, the main activity of the firm was showing their product at fairs and exhibitions, although the retail market was experiencing a bad time in 2009; linked to the financial crises in 2008. The sales of beds had been significantly reduced compared to sales in 2007 and 2008. The high-end market in Europe was not taking off and therefore, the team decided to focus its efforts in sales within the hospitality market until the situation in the retail market had improved.

6.3.5. Phase IV: Sales and development of a new application

In 2011, Start Green Venture Capital, which is an early-stage clean-tech venture fund, started investing in Evening Breeze to support the firm during the commercialization phase. Between 2011 and 2014, the main revenues of Evening Breeze were from Start Green and sales to a number of resorts all over the world. Figure 6.59 gives an overview of actions taken in phase IV.

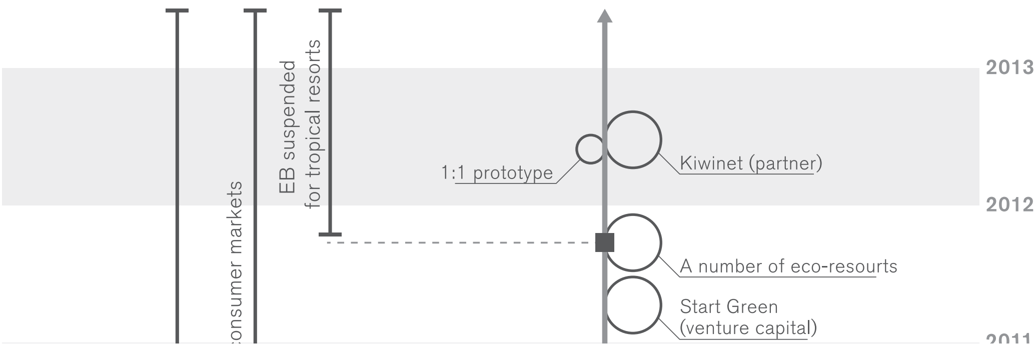


Figure 6.59. Design and stakeholder cycles throughout phase IV

Development of suspended version

In the summer of 2011, Evening Breeze modified the four-poster climate system so that the ventilation system was suspended from the ceiling and made use of a mosquito net. This came from a request from a resort that did not use four-poster beds. At the time, the firm considered this to be an exception; however, during their interactions with other resorts, the team realized that many resorts do not have four-poster beds and would need the Evening Breeze system to be integrated with their mosquito netting. Such a setup also offered a 360° view of the environment. These insights led the team to develop a new application in 2012, called *Evening Breeze suspended* (Figure 6.60), which is an adaptation based upon the Evening Breeze four-poster system. The team built a 1:1 prototype within two months in order to see how it would look and to send it to the producer in China.

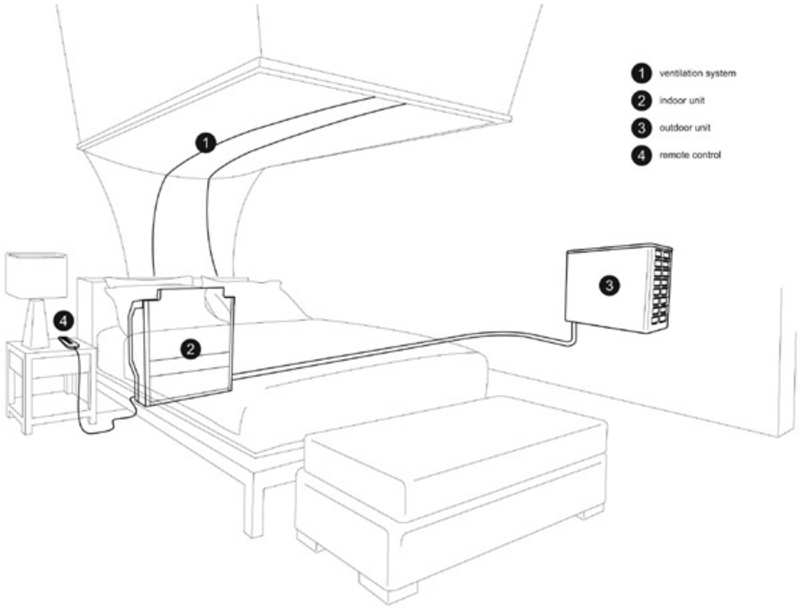


Figure 6.60. Evening Breeze suspended

Partnership with Kiwinet

The interactions with tropical resorts led to a partnership with a mosquito net manufacturer, Kiwinet. The resorts that owned mosquito nets from Kiwinet were interested in buying Evening Breeze cooling systems; however, were complaining that it was not possible to fit the mosquito net and the ventilation system of Evening Breeze within one frame. Currently Evening Breeze offers its suspended version with the option to combine it with mosquito nets from Kiwinet. Figure 6.61 shows an example of an installation in a resort.

Figure 6.61. Installation of Evening Breeze suspended

6.3.6. Conclusions Evening Breeze case

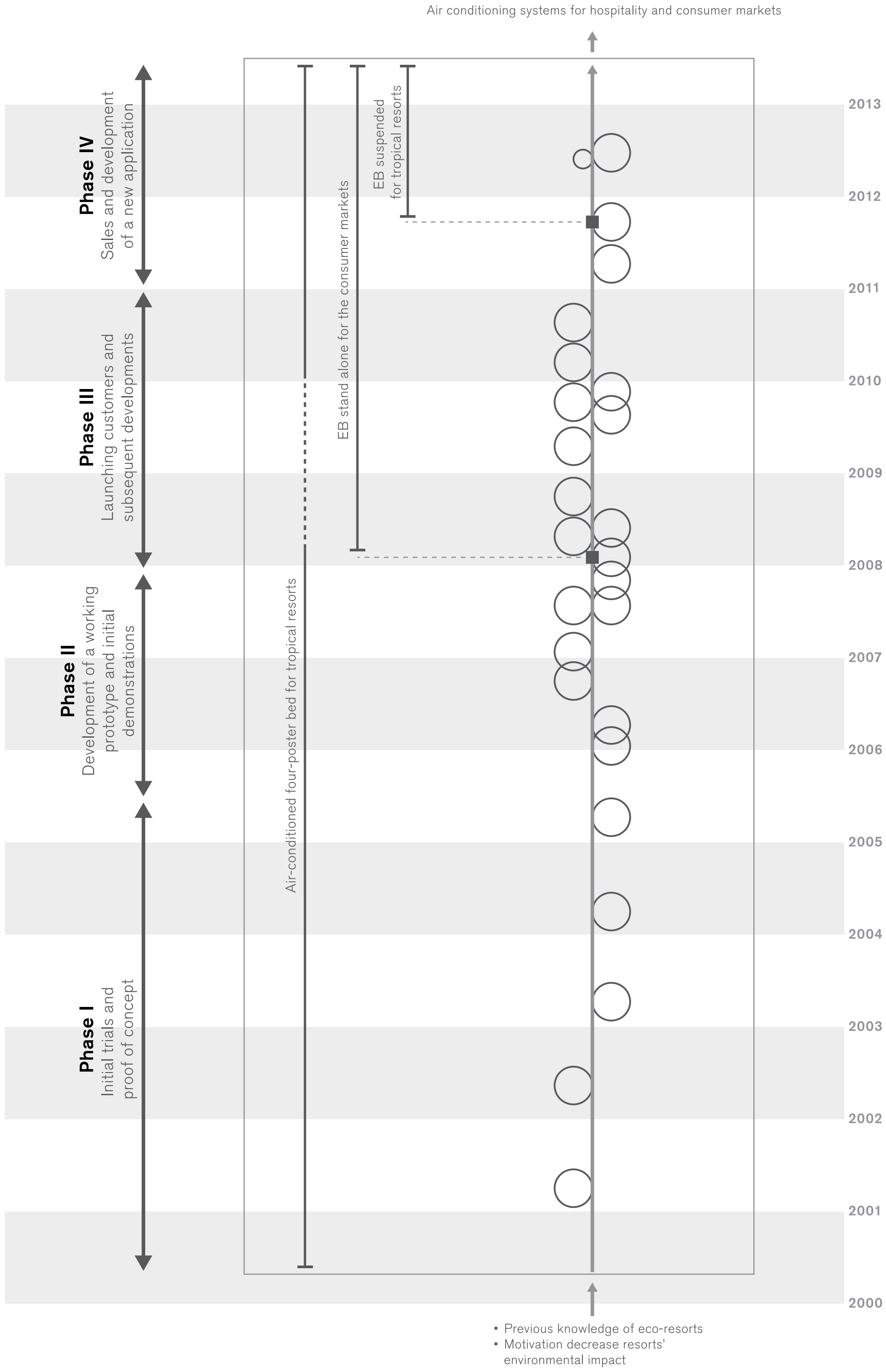
As illustrated in Figure 6.62, the innovation process of Evening Breeze is categorized into four phases. The first phase consisted of quick and affordable trials conducted by the ambassadors of the concept in an effort to test the feasibility of an air conditioning bed. Although the results were promising, the speed of the project declined until the involvement of Thomas van den Groenendaal and Yoeri Nagtegaal in 2005. In the second phase, the team initially put its efforts into building a working prototype, which could be tested with actual guests in tropical conditions. This prototype led to a demonstration project in five different resorts in South Africa and Curacao. With positive feedback of resorts and having won various competitions, Evening Breeze was able to convince investors for further development. These developments resulted in the setup of production in China for the third phase. In this third phase, the focus of Evening Breeze was shifting towards the consumer market and to the development of a stand-alone version of the system. In addition, launching customers from the consumer market with huge orders were significant developments during this phase. Due to the decline in demand in the consumer market, the firm shifted its focus back to the hospitality market. Due to a shift to hospitality market, this third phase ended with the development of the production model of the new version of the four-poster system. In the last and current phase of the innovation process, Evening Breeze has been focusing on sales and growth in the hospitality market and the development of a new application based upon the requests from customers. Table 6.3 gives an overview of Evening Breeze's iterations.

Table 6.3. Overview of Evening Breeze's iterations

Phase	Iteration #	Period	PM definition
1	Initial PM	2006 – 2013	An air conditioning bed for hospitality market (Evening Breeze four-poster)
2	1	2009 – 2013	An air conditioning bed for western consumer market (Evening Breeze stand-alone)
3	2	2010 – 3013	Evening Breeze four poster for hospitality market
	3	2011 – 2013	Evening Breeze Suspended for tropical resorts

Selection of the initial PM combination

The founders Visser and van den Brink aimed to develop an energy efficient cooling solution for resorts in order to decrease their environmental impact, as well as energy costs associated with air conditioning. Stemmed from the observation that cooling is necessary only during sleeping, the idea of an air-conditioning bed emerged, which would decrease the cooling space significantly and thus the energy consumption. The selection of an application related to eco-tourism can be explained by the initial means of the founders, i.e. their sustainability motivation as well as the previous experience and knowledge in eco-room projects.


Air conditioning systems for hospitality and consumer markets
Phase IV
Sales and development of a new application
Phase III
Launching customers and subsequent developments
Phase II
Development of a working prototype and initial demonstrations
Phase I
Initial trials and proof of concept
Air-conditioned four-poster bed for tropical resorts
EB stand alone for the consumer markets
EB suspended for tropical resorts
2013
2012
2011
2010
2009
2008
2007
2006
2005
2004
2003
2002
2001
2000
▪ Previous knowledge of eco-resorts
▪ Motivation decrease resorts' environmental impact

Decision on initial actions

Initial actions of the team going into design cycles appear to be explained by the low levels of perceived market uncertainty and low development cost of the prototypes. The initial prototypes were developed in order to test the feasibility of the idea, i.e. the amount of decrease in energy consumption. An existing air conditioner was used and a number of parameters were measured, such as the effective cooling time, the temperature and humidity in the bed and the room. Moreover, although the initial actions were design cycles, the team kept marketing the concept in resorts they visited during their professional activities. Approaching the design duo and going into a third design cycle (i.e. development of a scale model and working prototype) can be explained by the positive feedback they received from the resorts throughout 2003 and 2004. Besides the working prototype, a number of potential customers were contacted in order to receive input for the proposition and design of the AircoBed as well as gain their commitment to cooperate in pilot tests.

Consequence of actions and selection of subsequent iterations

Shift to Evening Breeze stand-alone for consumer market (iteration #1)

Successful results from the pilot tests with resorts and winning various awards enabled Evening Breeze to get the commitment of investors in the beginning of 2008. In this phase, Evening Breeze prepared for the setup of production of the Evening Breeze four-poster in China. During this time, Evening Breeze system also received attention from private customers and investors who were interested in investigating the potential within the consumer market. This resulted in a shift of the focus for the firm, as well as a number of design cycles in order to develop a stand-alone version of the Evening Breeze cooling system, which was financed by the initial investors. Based on the results of market research, the firm briefly investigated warmer and humid regions of the USA market, in which the product could be viewed as more of a necessity to sleep comfortably during the summer. Soon after this, the focus was moved to the Dutch consumer market, in which the Evening Breeze system would be a more luxury product. This decision can be explained by the positive feedback from the Dutch consumers and bed manufacturers, the investors' interest as well as their familiarity with the Dutch consumer market. Furthermore, the product concept was changing from a four-poster to a stand-alone version. This can be explained by the requirements of the consumer market, as well as the previous design experiments. The team was not satisfied with the rigid ventilation system in the earlier version, which also increased the shipping costs of the product. As a result, the Evening Breeze stand-alone was designed to include a fabric canopy placed over the bed in order to make the product appear integrated, while reducing the amount of materials and size of the rigid ventilation system in the earlier concept.

From consumer market to hospitality market (iteration #2)

Although the launch of Evening Breeze stand-alone was successful and led to cooperation with one of the biggest bed manufacturers in the Netherlands, due to the financial crises

« Figure 6.62. Overview of Evening Breeze's innovation process: phases, iterations and cycles

in 2008, the retail market was not doing so well in 2009. On the one hand, the sales of Evening Breeze stand-alone system were low; on the other hand, hospitality market, where the environmental benefits of Evening Breeze cooling system were higher, has never been abandoned. This resulted in the team focusing its efforts on sales in the hospitality market.

From Evening Breeze stand-alone to Evening Breeze suspended (iteration #3)

The development of the Evening Breeze suspended can be explained by the requests of current and potential customers of Evening Breeze. Many resorts who did not own four-poster beds or who wanted to combine the Evening Breeze system with their current mosquito nets were asking for modifications of the product. Evening Breeze adapted to these requests quickly and developed Evening Breeze suspended during the summer of 2012. Currently, the main sales of Evening Breeze are achieved through its suspended version.

6.4. CASE: VRACHTFIETS

The main interviews for the Vrachtfiets case were conducted with Louis-Pierre Geerinckx and Onno Smina, the founders of Vrachtfiets. The interviews took place in May 2010, September 2012 and September 2013. The research papers stemmed from Masters theses and web articles related to Vrachtfiets, business plans written by the entrepreneurs as well as the firm's website provided complementary data.

The Vrachtfiets case was selected for its moderate level of technological uncertainty. The initial phase of Vrachtfiet's product development process consists of early trials with immature versions of the product together with potential customers in an effort to find a feasible PM combination.

6.4.1. Introduction to the firm

Vrachtfiets, a name that combines the Dutch words for 'cargo' and 'cycle', is a spin-off firm from TU Delft in the Netherlands. The firm was founded in July 2009, with the vision of developing a sustainable and affordable mode of transport. Two industrial design engineers Louis-Pierre Geerinckx and Onno Smina started the firm based on a problem they had often experienced during their studies: transporting voluminous goods. They aimed at developing a cargo cycle with the idea of offering an affordable alternative to existing mobility solutions, and making students less dependent on motorized vehicles. A Vrachtfiets is an electric assisted modular cargo cycle that enables custom-made mobility solutions. Instead of a cargo 'module', any module can be designed for a specific context and provide a fitting mobility solution.

Summary of the evolution of the product concept

Since the idea first emerged, the cargo cycle concept has gone through a number of changes. The initial business idea of the founders was to offer Vrachtfiets as an affordable service to customers in need of transporting voluminous goods. Since moving voluminous goods require at least two people, the cycle was initially designed to accommodate two cyclists. Furthermore, the modularity of the system was envisioned to enable various smart mobility solutions through new applications in different contexts. There were several technical flaws with the first prototype; however, it led to new demonstration projects with the Municipality of Delft, and IKEA, the international mass-market retailer. The demonstration projects provided a test ground for Vrachtfiets to improve the design and explore different markets. One of the important things learned from these tests was that having a bicycle for two people increased the costs for the customers of Vrachtfiets. This led to a second design iteration, in which the cargo bicycle was designed to accommodate only one person. Furthermore, using the same base, they also designed a third iteration, a 'pick-up' module for demonstration purposes. The *pick-up version* was aimed at city services such as park maintenance. This third design iteration led to new customers, which enabled a new and improved design for the module, as well as the addition of a windshield in order to protect the driver from the wind and flying debris common in cities. In parallel to the smooth evolution of the cargo cycle, Vrachtfiets developed another application with different product architecture. This concept, *Vieco*, was designed for the Dutch government with the aim of offering public transport services to local tourists for the last mile of their trip, particularly at the end of a train ride. The module of Vieco was designed to be in the front enabling a better sightseeing experience for the passenger, with the bike seat and pedals located at the back.

Team composition

Since the idea was first percieved in 2007, Vrachtfiets' employees consisted only of the two founders who had a background in industrial design engineering. Before the firm was founded in September 2009, they had worked on Vrachtfiets as a side project throughout their studies. Since their graduation in May 2010, they both work full time on the design and development of the Vrachtfiets.

Sustainability motivation of the team

The Vrachtfiets idea emerged from the motivation to offer a sustainable alternative to existing mobility solutions for transporting voluminous good. This is reflected in (i) the efforts of the team in measuring the environmental impact of the cargo-bike concept, (ii) the adoption of strategies such as Cradle-to-Cradle*, during the design process, and (iii) the ambition to offer affordable solutions for the students in Delft. Although the team has pursued environmental goals throughout the whole innovation process, the level of priority of social goals was lowered upon realizing that the customers of the firm would not be the students.

Business model

Since the function of the Vrachtfiets depends on the type of cargo module connected, the initial business idea of Smina and Geerinckx was to offer various mobility solutions for different purposes in a number of markets. This idea was tested in various demonstration projects with different partners. Some of the markets tested were: inner city distribution, after school transport and tourism on islands. All these one-off projects and probes enabled the concept to evolve in a smooth fashion. At the end of 2012, the team came to the conclusion that iterating in order to improve the design of the base and to design new modules for different markets would not enable them to grow fast. As of 2013, Vrachtfiets has put its efforts in sell bicycles in quantities, with a focus on the cargo and pick-up version of the Vrachtfiets through partners with a licensing model.

** Cradle-to-Cradle is a sustainable design philosophy, which integrates the processes in nature and advocates the up-cycling of materials by using them over and over.*

Financial resources

During 2009 and partly 2010, Vrachtfiets gained revenue mainly from subsidies and one-off projects with various organizations. Between 2010 and 2013, their main revenue was gained through a government grant focusing on sustainability, innovation and international business. Vrachtfiets has invested approximately €70,000 throughout 2009 and 2010, and approximately €300,000 between 2010 and 2013 for the design and development of various versions of cargo-bikes.

Overview of PM iterations, design experiments and stakeholder interactions

The following paragraph describes the iterations of Vrachtfiets over time. Figure 6.63 illustrates the design and stakeholder cycles Vrachtfiets engaged in since the idea first emerged. The first phase between 2007 and 2010 is characterized by the development of the first prototype and a demonstration project on Ameland, a Dutch island. This phase is followed by a phase of initial demonstration projects with paying customers and a phase of subsequent demonstrations. The last phase is characterized by experimentation in different markets with different applications.

In the following paragraphs, each phase will be explained through a detailed description of the PM combinations and an overview of actions, in terms of stakeholder cycles and design cycles. The PM combinations, stakeholder and design cycles are determined by their centrality in interviews as well as complementary documents.

6.4.2. Phase I: Initial PM trials

The product idea behind Vrachtfiets came from the question: 'How can students without a driving license transport larger items such as a cabinet or a sofa to their home without having to ask for the help of parents?' For instance, Onno Smina explains, *"My parents had to drive 200 kilometers to me in order to transport my couch for two kilometers. Then you wonder if that can not be smarter."* The business idea was further developed within a course called 'Writing Business Plan' at YES!Delft, the incubator for start-ups at TU Delft (see Figure 6.64 for an overview of actions taken during phase I). The initial business idea was to sell and rent the modular cargo cycle within different markets by offering custom-made mobility solutions. The built-in modularity was expected to facilitate different business opportunities. Not surprisingly, the first market segment chosen was the students in Delft since the young entrepreneurs of Vrachtfiets were students at TU Delft at that time and thus had a good network among students and organizations that would be willing to sponsor the project. The idea was to offer a solution to students to transport voluminous goods from one place to the other, for instance, from retail shops to their homes.

As a next step in 2008, Vrachtfiets participated in a competition called 'Duurzame Dinsdag' (in English: Sustainable Tuesday), which is an annual competition organized by the Dutch government to stimulate and award sustainable community ideas. Although they did not win this competition, they were given a recognition, which put them in the scope of Delft

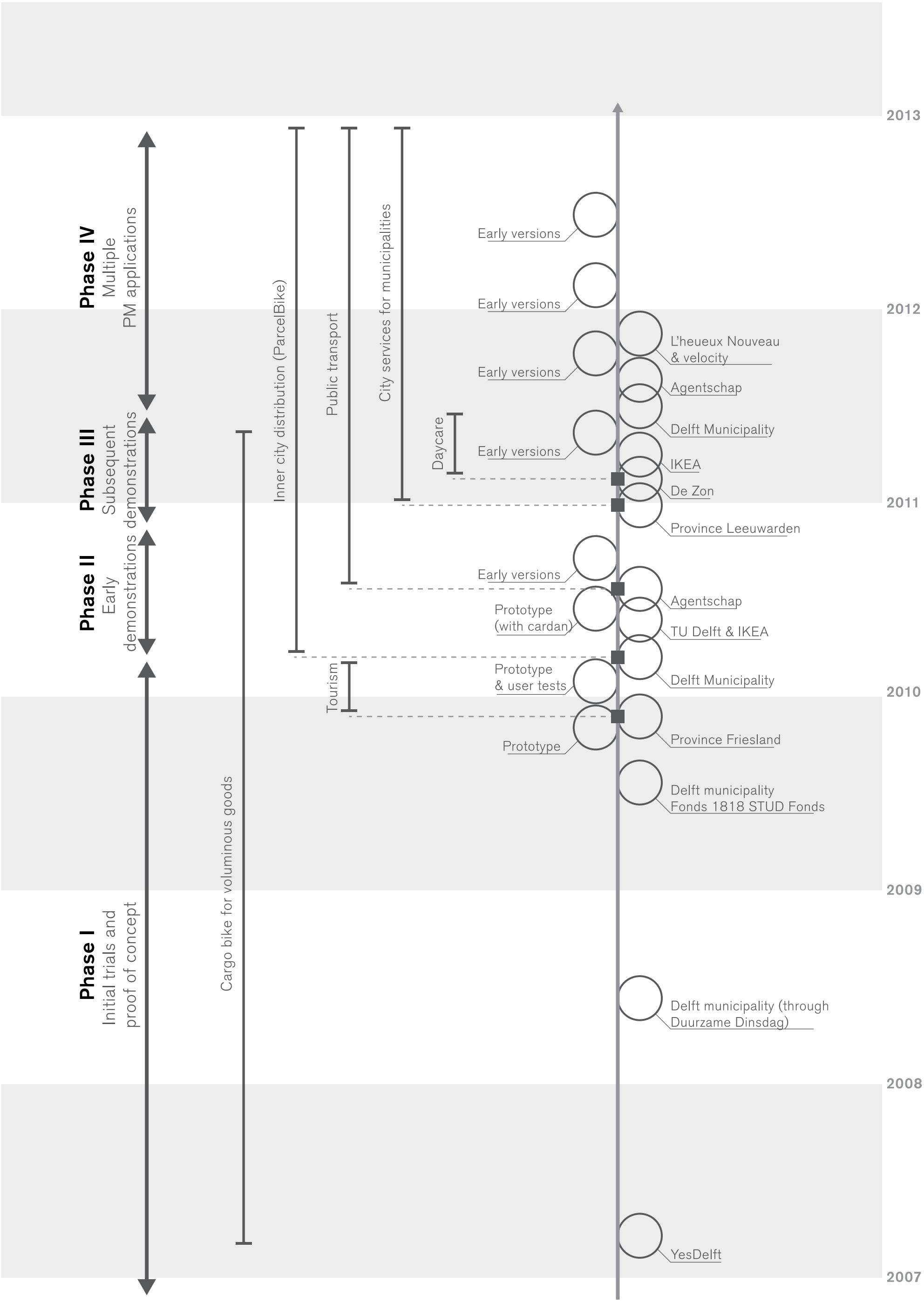


Figure 6.63. Overview of Vrachtfiets' innovation process: phases and iterations

Municipality. In order to get funding for building the first prototype, Vractfiets initially contacted a number of stakeholders. During the period of June-September 2009, they interacted with STUD Fonds, Fonds 1818 and Delft Municipality. STUD Fonds is a non-profit organization that aims to support TU Delft students in finding interesting jobs by bringing them in contact with businesses. STUD Fonds became interested in Vrachtfiets because the project would benefit the students. Fonds 1818 is an equity fund that supports social projects in the region of Delft, The Hague, and Leiden. Delft Municipality was interested in projects related to sustainability, and was searching for alternatives for inner city distribution. They wanted the prototype to be public, as a political statement for a green city. With funding from these three stakeholders, Vrachtfiets was able to built the first prototype between October 2009 and January 2010 (Box 6.9). The public presentation of this prototype took place in February 2010 in the presence of the Delft municipal councilor of inner city and environmental affairs. This provided publicity and resulted in a series of stakeholder interactions.

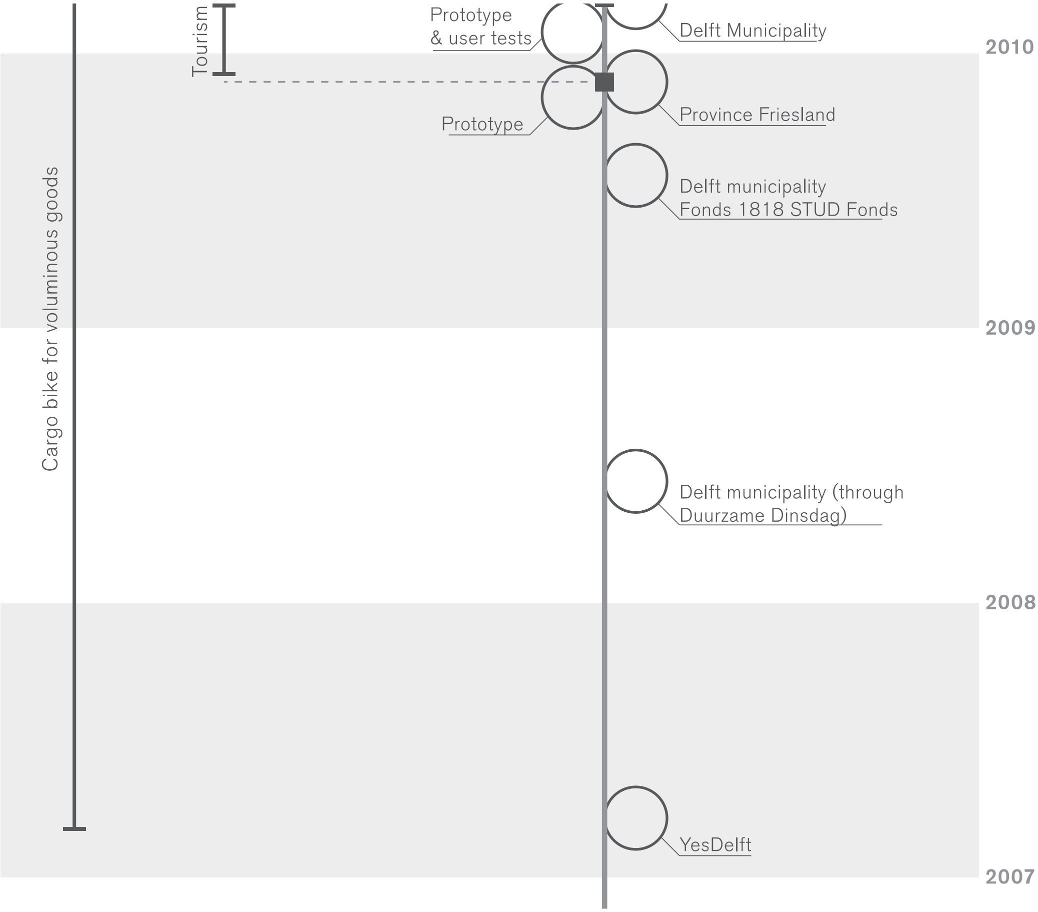


Figure 6.64. Initial actions in phase I

Box 6.9. The initial design and first prototype
Since the initial market was chosen to be students in Delft who wanted to transport voluminous goods over short distances, the first prototype of Vrachtfiets was designed to be powered by two people; sitting next to each other at the front end of the vehicle. Furthermore, it was electrically assisted to make the transportation easy and convenient. The seats had a semi-recumbent position for ergonomic reasons. In a recumbent position, riders can use their own weight in order to paddle with less effort. A recumbent position has also an aerodynamic advantage; due to reclined position the frontal surface of the rider's body get lower, enabling a more streamlined and comfortable ride.

Another property of the first prototype was that the transmission was enabled through a roller chain that transferred power of the rider from the pedals to the wheel of the bicycle. The reason they chose a chain as the transmission method for Vrachtfiets was its availability in the market, but also its match with suppliers' knowledge and skills.

Lastly, the cargo module was designed big enough to accommodate voluminous goods. A roll curtain was placed at the back of the module enabling ease of transport for particularly long items.

First prototype of two person Vrachtfiets

During the construction of the first prototype, the team came into contact with the Province of Leeuwarden through their personal network. The Province was interested in a sustainable alternative for the mobility of tourists on Ameland. As a result, the tourist module was prototyped at beginning of 2010, and mounted on the same base as the first prototype. The module was designed to accommodate at least two people and eight bags (two per person); parents would propel the bicycle while the children are safely stored in the module. Furthermore, the module had a clear separation between the people and the luggage areas (Figure 6.65).

A user test was conducted in February 2010 with the customers of a Bungalow Park on Ameland. The general reaction of the participants was immediate enthusiasm and willingness to try the Vrachtfiets. Four out of five tourists claimed that they would use the bicycle if it was available. All tourists stated that the main reason they prefered to use a car was their kids and luggage. They also indicated that the option for reservation before coming to the island was an important factor in convincing them to leave their cars on the mainland.

Figure 6.65. Tourist module for Ameland project (left) and user tests (right)

Outcome of Phase I

During the construction of the prototype as well as during the user tests, the firm discovered a few technical flaws, particularly with the chain and the location of the pedals. As the pins that join the chain-links together wear out over time, chains usually stretch and become loose during use. The Vrachtfiets is a long vehicle and requires a long chain, which created problems during usage and required constant maintenance. Another issue with the first prototype was the location of the pedals; they were in the front and were vulnerable if the bicycle hit something.

6.4.3. Phase II: Subsequent PM iterations, early demonstrations and launching customers

As soon as the founders of the firm finished their studies in May 2010, they began working full time in the improvement of Vrachtfiets; design of new applications based on different modules, as well as the development of the business. Figure 6.66 gives an overview of actions taken during phase II. During the second and third quarter of 2010, Vrachtfiets interacted and closed deals with a number of stakeholders such as the Municipality of Delft, TU Delft, and IKEA. These interactions led to a number of prototypes and probes, which were mainly concentrated in the second and third quarter of 2010.

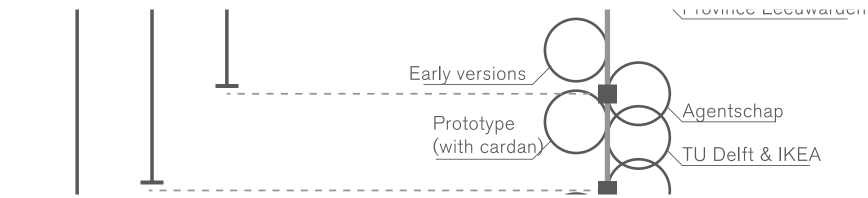


Figure 6.66. Design and stakeholder cycles throughout phase II

The same contact from the Municipality of Delft, who partially subsidized the development of the first prototype, was also involved in projects related to air quality and noise reduction. He was interested in starting a project with bicycle messengers carrying parcels for PostNL. Vrachtfiets would produce cargo cycles. In addition, Combiwerk, a social workplace offering custom work to people who are not able to find a regular job (e.g. due to a physical, psychological or mental limitation), would be responsible for the maintenance of cycles as well as the delivery of parcels. Using a cargo cycle for parcel delivery and collaboration with the social workplace was a test for the Municipality of Delft. The municipality was interested in exploring the possibility of involving people from social workplaces, instead of professional messengers, thereby lowering the costs as well as creating jobs for the unemployed. Therefore, they requested a Vrachtfiets, which would provide parcel delivery services to the inner city of Delft. In this probe, the firm aimed at trying a different transmission system due to the issues related to chain in the previous prototype. They started building a bicycle with a ‘cardan’ shaft drive, similar to a car transmission system. In a cardan shaft drive, a mechanical component is used instead of a chain in order to transfer power from the pedals to the wheels (Figure 6.67). Furthermore, in a cardan system, bevel gears are used instead of traditional gears. The Vrachtfiets is hand built, therefore the alignment of the front and rear gears became a huge technical challenge. The tolerance of the cardan system to misalignment is very low compared to a chain system, i.e. even low degrees of misalignment could bend the shaft and decrease the lifetime of the product considerably. The firm tried, but failed to solve the misalignment issue linked to the cardan system. A prototype was built for the Delft municipality during mid 2010; however, never delivered. Eventually, they decided to continue with chain and solve the challenges related to it. Furthermore, the municipality requested another prototype.

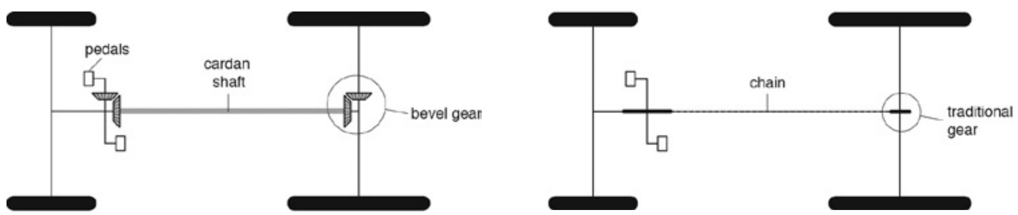


Figure 6.67. Top view of transmission through cardan versus chain

Meanwhile TU Delft contacted the firm with an interest in buying a custom-made Vrachtfiets. Several times a year, national and international organizations contact TU Delft Faculties and individual staff members for demonstration projects in the area of sustainable design. Therefore, TU Delft, particularly IDE was interested in showcasing sustainable innovations that were developed within the faculty. Among others, Vrachtfiets was considered to be a successful case of a sustainable design as an alternative to a normal freight system. Previously, during the development of the tourist application in the Ameland project, a comparison between the Vrachtfiets and cars was made. It was calculated that the Vrachtfiets based transport system had an environmental impact of only 1.3% of that of cars. The assignment for the TU Delft showcase was to create a TU Delft Vrachtfiets version that included a mobile and flexible exposition of sustainable innovations and promotion material on sustainability programs, from all TU Delft faculties and programs. Therefore, the team aimed to design a custom-made version of Vrachtfiets, which could be used as a mobile exhibition stand for TU Delft.

In parallel to the interactions with the Delft Municipality and TU Delft, the firm was in the process of making a deal with IKEA. IKEA was interested in offering an alternative to its customers for transporting IKEA items to their homes. For IKEA, cargo cycle was a new idea and they were interested to explore if Vrachtfiets would be a suitable solution.

Due to these parallel interactions, Vrachtfiets aimed at producing the four bicycles partly in parallel to ease the production process, but also in a sequence in order to improve the bicycles at each step. Most materials for all of the bicycles were purchased together, but the firm decided to start with building the bicycle for TU Delft first. This was delivered in August 2010 (Figure 6.68). The bicycles for the Municipality of Delft (Figure 6.69) and IKEA (Figure 6.70) were delivered in September and October 2010, respectively. Box 6.10 gives a description of the bicycles for TU Delft, the municipality and IKEA.

Figure 6.68. TU Delft probe

Figure 6.69. Probe for the Municipality of Delft

Figure 6.70. Probe for IKEA

Box 6.10. Description of probes for TU Delft, Municipality of Delft and IKEA
Due to problems related to the position of the pedals and safety requirements in the first prototype, the firm decided to use an upright sitting position in the new version of Vrachtfiets. An upright position provided a much better overview of the traffic in both front and back. In an upright position, the rider can look back over the cargo area a lot easier, which was not possible in the previous version.

Furthermore, in this series of probes the firm tried different setups linked to the location of the engine. In the first prototype, the engine was placed in one of the front wheels, which made one side of the bicycle heavier. In order to increase the stability, balance and power of the bicycle, they placed two engines in each of the front wheels for the TU Delft probe. This setup created a lot of noise during usage since the front wheels had internal gearing; therefore, the probes for the Municipality of Delft and IKEA were constructed using the single-engine setup.

Outcome of Phase II

The collaboration with TU Delft, the Municipality of Delft and IKEA created a test ground for Vrachtfiets to improve the design and explore different markets. From a technical perspective, the team realized that the bicycles were not robust enough for how people were using them. Furthermore, the cycles had problems with the spokes in the wheels due to the engine located in the front wheel. The engine was quite large so was not possible to cross link the spokes, which would provide strength and increase the durability of the wheels.

Using cargo cycles for transporting goods was new for IKEA and they were interested in testing if a Vrachtfiets would be suitable for this purpose. The test was mainly successful and Vrachtfiets was offered to IKEA's customers. Unfortunately, while two customers were using the cycle, it got a flat fire. IKEA was not able to pick it up immediately as it happened on a Sunday evening. They brought the customers and IKEA items to their home but decided to leave the cycle. Unfortunately they found it completely destructed next day.

During the tests for the Municipality of Delft and collaboration with the social workplace, the team discovered that a roll curtain on the rear side was not as useful as it was for IKEA. They had made a quick fix and added an extra roll curtain at the corridor side; this made the loading and unloading process easier for the messengers. Despite this, the test eventually failed and the idea was abandoned. Financially, the parcel delivery is a difficult market with low margins, and two-person aspect of the Vrachtfiets increased the costs of the parcel delivery.

6.4.4. Phase III: Subsequent PM iterations and demonstrations

After the initial demonstrations, a number of organizations contacted Vrachtfiets to order bicycles with different functions (see Figure 6.71 for an overview of actions taken during phase III.). The first two customers were the Province of Leeuwarden and a daycare firm called 'de Zon'. The Province of Leeuwarden was interested in a custom-made Vrachtfiets, i.e. a pick-up version, to use it for city services, particularly for the maintenance of inner city areas. Furthermore, because TU Delft and the Municipality of Delft were using Vrachtfiets in their marketing tools, they received some attention, leading to the contact de Zon, who was interested in a cycle to transport children from school to an after school care facility, which is expensive and usually done by an external firm. This led to the design of the daycare version.

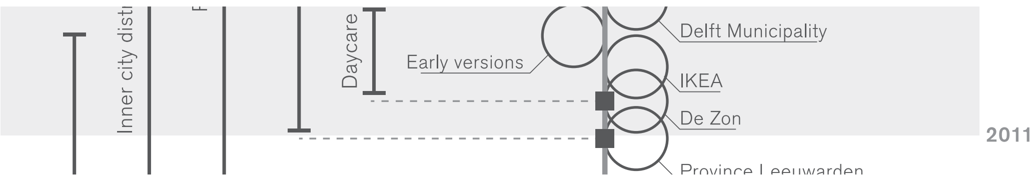


Figure 6.71. Design and stakeholder cycles throughout phase III

The probes for the Province of Leeuwarden and de Zon were built mainly in parallel during the first half of 2011, accommodating the same base but different module design (Figure 6.72 and 6.73). Box 6.11 gives an overview of the attributes of these probes.

Just after building of the pick-up and daycare version, IKEA requested another cargo cycle. IKEA was interested in continuing the test with the Vrachtfiets, but the time frame of the request was short. Therefore, the base that had been built for the pick-up version was used in this probe. The cargo module design was updated and a new module was built for IKEA (Figure 6.74).

Figure 6.72. Pick-up version

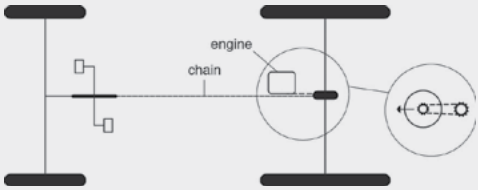
Figure 6.73. Daycare version

Figure 6.74. Cargo version

Box 6.11. Description of probes for Province of Leeuwarden, De Zon and IKEA
This version of Vrachtfiets was designed to be 3.5 m long and 1.1 m wide. The cargo module offered a flat surface of 2.0 by 1.0 m. The frame had been designed to withstand cargo of around 400 kg. It had a 36-volt electrical support that delivered an average power of 250W to increase the comfort of the cyclist(s) as they ride. The motor derived power from a lithium-ion battery with a capacity of 12 Ah that lasted approximately 6 hours. The battery could be disconnected from the vehicle for charging using a standard socket.

The cargo module featured a plastic sliding hatch with a closed cargo area of 2.0 m x 0.95 m x 1.0 m (l*w*h). The pick-up module similarly featured the same cargo area of 2.0 meters x 0.95 meters with a height of 0.4 m. The daycare module was designed to accommodate around ten children between the ages of 4-12. Their mentor could be aided in cycling by either a colleague or one of the older children. The entrance of the module, which had a lock, was located at the curbside. The module consisted of safety belts for each child and a place to store their bags.

Furthermore, due to the location of the engines and issues with the spokes of the wheels, in this version the engines were placed on the rear side between the wheels with an extra chain on the wheels.



Outcome of Phase III

Technical issues particularly with the chain continued to be a problem in this version. An additional challenge of the chain elongation in this setup was linked to the location of the engine. In order to have enough tension in the chain, the motor had to be moved slightly to the back (see Box 6.11 for detail). The cycles also required regular maintenance, particularly the cycles for IKEA as it was being extensively used.

6.4.5. Phase IV: Multiple PM applications

After the second phase of demonstration projects with the Province of Leeuwarden, de Zon and IKEA, the Municipality of Delft requested two more cargo cycles for the same purpose of parcel delivery (see Figure 6.75 for an overview of actions taken during phase IV). This time they were interested in the one-person cargo cycles in order to decrease the costs of personnel. In this version, the roll curtain of the cargo box was moved from the rear side to the corridor side (Figure 6.76). Another attribute of this version was a windshield, which was included in the design in order to protect the driver from wind and flying debris common in cities.

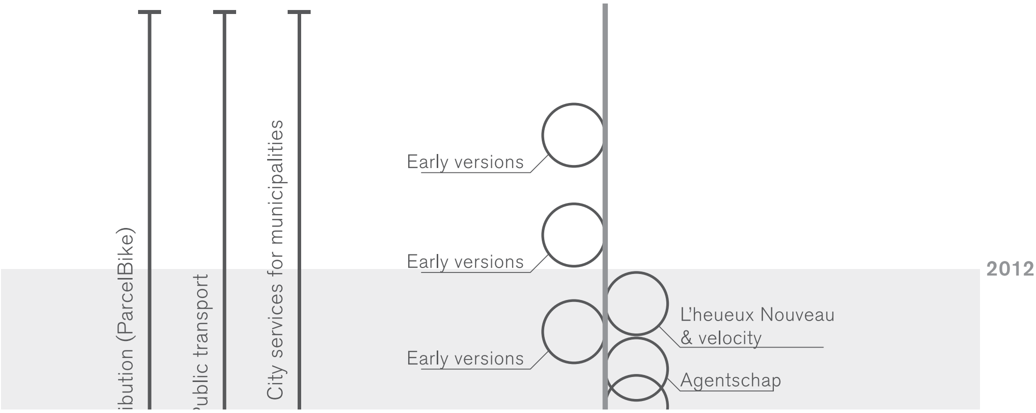


Figure 6.75. Design and stakeholder cycles throughout phase IV

In parallel to the second probe for the Municipality of Delft, the team built another pick-up version for demonstration purposes (Figure 6.77). The pick-up version was lent to the Municipality of Rotterdam as well as social workplaces in Rotterdam in order to demonstrate the product but also to test it on a number of parameters such as robustness, use, and business viability. The bicycle was also demonstrated at various fairs.


Figure 6.76. Second probe for the Municipality of Delft


Figure 6.77. Pick-up version with one seat

Probes for parcel delivery businesses

These developments led to two new customers at the end of 2011: Velocity, a bicycle courier firm in Nijmegen and L'heureux Nouveau, a vegetable delivery firm in Brussels. Velocity offers on-demand shipment services to a range of organizations, from law firms and educational institutions to museums in Nijmegen and surroundings. Velocity also provides custom services to a range of organizations, e.g. internal messenger services for companies, daily deliveries for hospitals, wholesales, laboratories, and lunch and grocery services for businesses. The parcels are delivered by couriers using a number of different vehicles such as bicycles, trailers and cargo cycles. Velocity became interested in Vrachtfiets as they aimed at offering vegetable delivery to the inhabitants of Nijmegen and both Velocity and L'heureux Nouveau were interested to explore if a Vrachtfiets would be a suitable solution for such a service. Furthermore, L'heureux Nouveau sells organic vegetables and was interested in presenting themselves as a sustainable business to their customers.

Vrachtfiets delivered one cargo cycle for Velocity and two for L'heureux Nouveau during the first quarter of 2012 (Figure 6.78). The same design based on the last probes was used with some minor improvements.

For most customers of Vrachtfiets, the image of being sustainable was an important reason for buying a Vrachtfiets, and in using such a bicycle, their business became eye-catching. For instance, L'heureux Nouveau mentioned that each time they rode through Brussels, they gained new customers as people were curious about Vrachtfiets and wanted to learn about the business. These tests proved that Vrachtfiets had also become a strong marketing tool.

Figure 6.78. Probes for L'heureux Nouveau and Velocity

Collaboration with Agentschap

Since August 2010 (Phase II), Vrachtfiets received an innovation subsidy from Agentschap, a division of the Dutch Ministry of Economic Affairs that carries out policy and subsidy programs focusing on sustainability, innovation, international business and cooperation. With this subsidy, Vrachtfiets received an assignment to develop a smart solution for passengers with luggage to travel to and from the station, which led to the tourist version of Vrachtfiets. The aim of the assignment was to encourage local holidaymakers to use the train in combination with Vrachtfiets and leave their cars behind, *"After arriving at the train* *station, tourists could use Vrachtfiets to travel with children and luggage to their holiday destination"* (SBIR, 2011). The first phase of this assignment was a feasibility study, which was conducted from August 2010 until February 2011, in order to identify relevant stakeholders for an envisioned solution and demands of the potential travelers. This feasibility study was conducted in parallel to the demonstration projects in Phase II and III. It was successfully finalized in February 2011, which enabled the firm to continue to receive funding for the implementation phase. The firm spent the first half of 2012 on building seven tourist cycles and conducted a user test throughout the summer of 2012 (Figure 6.79). The module of the tourist version was designed to be in the front for better experience for sightseeing and interaction between children and parents. Furthermore, from a safety perspective, parents felt much more in charge as they could continuously check their children.

Figure 6.79. Tourist version (left, middle) and user tests of the tourist version(right)

Outcome of Phase IV

Designing a custom-made cycle for each customer was a time consuming process. Therefore, after completing the Phase IV probes and having interactions with various potential customers, the team decided to focus on only two versions: the cargo and pick-up cycles. The cargo version was mainly aimed at parcel delivery businesses; this version could be closed and locked. The pick-up version was designed for city services such as park maintenance and waste management. During the end of 2012, they aimed at improving the design of the base from a technical perspective, and meanwhile developing an order portfolio in order to start selling at the beginning of 2013. As Louis-Pierre Geerinckx recalls in an interview in September 2012, "We have this motto: it cannot break down".

Meanwhile, the durability of the cycles and maintaining them became an obvious issue with the probes of Phase IV. The delivery companies such as L'heureux Nouveau and Velocity had been using the Vrachtfiets everyday. Most bicycle parts were not designed to be used extensively in rough environments. If one component breaks, no matter how cheap it is; these businesses cannot make money that particular day. The bicycles were not robust enough and maintenance became a time consuming issue for the small team of Vrachtfiets during the end of 2012.

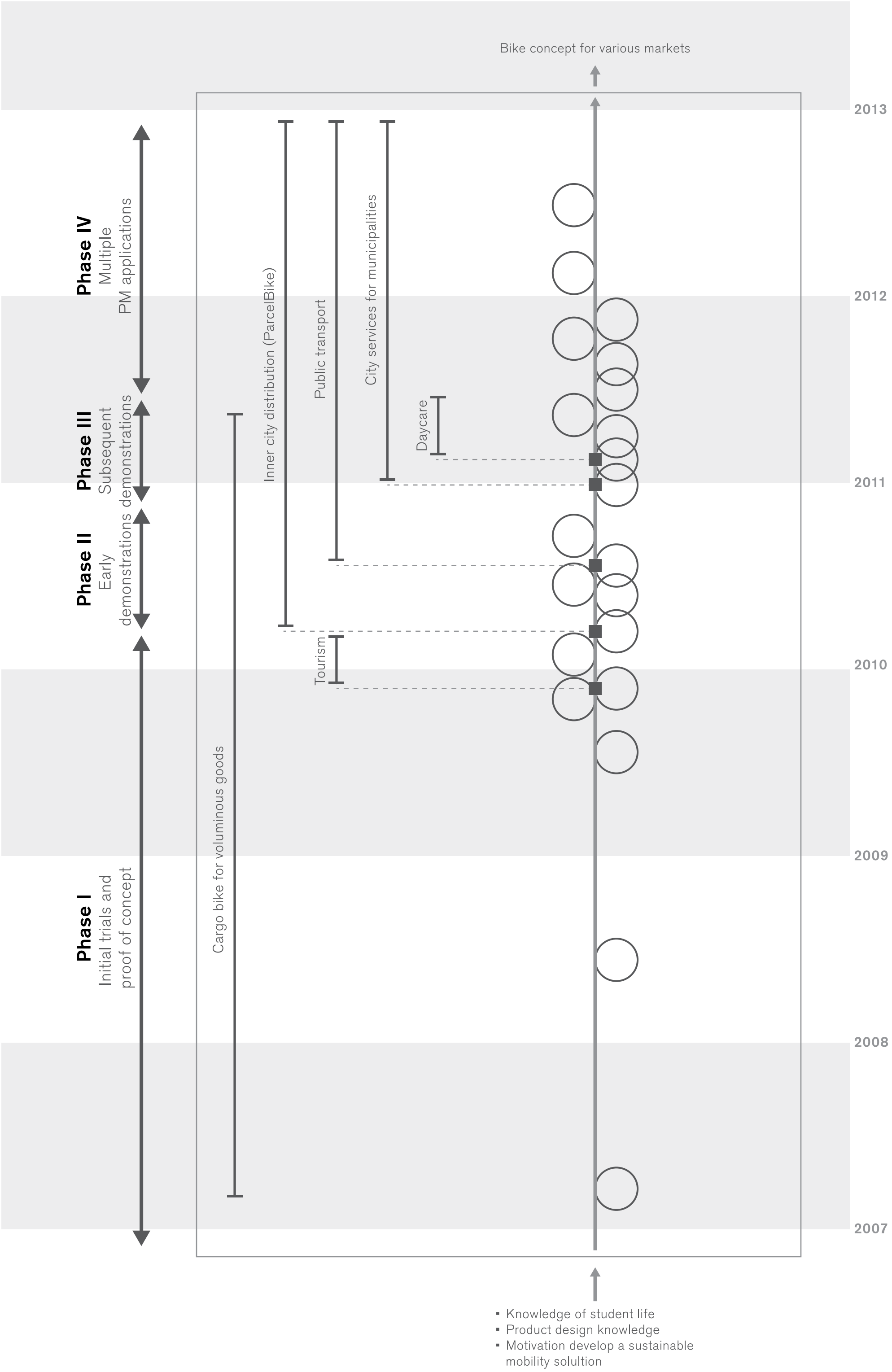
These developments led the team to conclude that the current business model was not successful, as Louis-Pierre Geerinckx states, *"If we grow now, we scale up our problems"*. Therefore, the firm began looking for opportunities for a different business construction, such as licensing. In of the beginning of 2013, the firm was looking for a producer who could license and produce Vrachtfiets, as well as a customer who would buy from this producer.

6.4.6. Conclusions Vrachtfiets case

In Figure 6.80, Vrachtfiets' innovation process is illustrated and categorized into four phases. The first phase consists of a long gestation period of the business design and initial trials for the development of a proof of concept of a cargo cycle for voluminous goods. In the second phase, the firm built a series of probes mainly based on the requests from their immediate network such the TU Delft and the Municipality of Delft. In this phase, IKEA also ordered a bicycle. Although the focus of each customer was slightly different, i.e. voluminous goods, parcel delivery, exhibition; these probes mainly focused on the development of the cargo version of Vrachtfiets with slightly different module designs. In this phase, the semi-recumbent position was transformed into an upright position. Furthermore, a different transmission system was tested and failed due to the issues of misalignment. Similar to Phase II, the third phase involved one-off projects based on the requests of a variety of organizations such as the Province of Leeuwarden, daycare firm de Zon and IKEA. In this phase, different module designs such as the daycare and pick-up modules were tested based on the requirements of the customers. The fourth and last phase of Vrachtfiets' innovation process involved one-off probes for different organizations, as well as a large demonstration project for the government involving the development of seven tourist cycles. In the beginning of 2013, Vrachtfiets was looking for exit strategies in order to hand over the design and business to other parties.

Table 6.4. Overview of Vrachtfiets' main iterations

Phase	Iteration #	Period	PM definition
1	Initial PM	2007 – 2011	Cargo cycle for voluminous goods
1	1	2009	Tourism in islands
2,3,4	2	2010 – 2013	Parcel delivery
2,3,4	3	2010 – 2013	Public transport
3	4	2011	Daycare cycle
3,4	5	2011 – 2013	Pick-up cycle for city services



Bike concept for various markets
2013
2012
2011
2010
2009
2008
2007
Phase IV
Multiple
PM applications
Phase III
Subsequent
demonstrations
Phase II
Early
demonstrations
Phase I
Initial trials and
proof of concept
Cargo bike for voluminous goods
Inner city distribution (ParcelBike)
Public transport
City services for municipalities
Daycare
Tourism
▪ Knowledge of student life
▪ Product design knowledge
▪ Motivation develop a sustainable
mobility solultion

Selection of the initial PM combination

The idea of Vrachtfiets was born in 2007 with the motivation of developing a sustainable and affordable mobility solution for dense city centers. The selection of an application related to freight can be linked to a problem often experienced by the founders of the firm and their student network. When students wanted to transport their voluminous goods, it was often a problem; either they needed to arrange an expensive van or ask their parents, who often live in a different city to drive to Delft to transport a piece of furniture for a short distance. During their studies in Delft, the founders of Vrachtfiets decided to tackle this problem and aimed to develop a cargo bicycle which would be affordable and environmentally more sustainable compared to the alternative solutions. The selection of the initial PM combination can be explained by the initial means of the founders, particularly 'what I know'. They both had design background and were interested in using their design knowledge to create something tangible for a problem they themselves experienced as well.

Decision on initial actions

Throughout 2007 and 2008, the team was developing the product and business idea within the course of their studies. In 2009, when they decided to build a prototype, they contacted a number of governmental organizations for funding. The early focus of a cargo-bike, the development of a working prototype and consequent search for external resources appears to be explained by the low level expertise of entrepreneurs.

Consequence of actions and selection of subsequent iterations
Rather than a sequential fashion, Vrachtfiets was engaging in parallel PM iterations throughout the whole innovation process. Although they were interacting with various organizations from different target markets, the team mainly developed four applications; namely cargo, pick-up, daycare and tourist cycles.

Shift to tourism (iteration #1)
Vrachtfiets focused its early developments around the cargo cycle in order to reach retailers such as IKEA. During this period, the firm has been interacting with several governmental organizations, which led to different applications in the subsequent phases. In that sense, the idea for a tourist cycle was born during the interactions of the firm with Province of Friesland, who requested a tourist cycle for tourists visiting Ameland.

Shift to parcel delivery (iteration #2)
In order to get funding for the development of the first prototype, Vrachtfiets came into contact with the Municipality of Delft. This led to the development of a parcel delivery version since the municipality was interested in developing projects related to air quality and noise reduction. Therefore, this iteration can be explained by the interactions of the firm with stakeholders.

« Figure 6.80. Overview of Vrachtfiets' innovation process: phases, iterations and cycles

Shift to public transport (iteration #3)
The idea for integrating Vrachtfiets into the public transport system was born during the interactions with Agentschap, a division of the Dutch Ministry of Economic Affairs that carries out policy and subsidy programs focusing on sustainability, innovation, international business and cooperation. In this process, Vrachtfiets received an assignment to develop a smart mobility solution for local tourists to enable them to travel from train stations to their point of accommodation. The decision to go into public transport is a direct outcome of this interaction and can be explained by firm's financial needs and survival.

Shift to daycare (iteration #4)
The daycare market was a short-term iteration. After the initial demonstrations, a number of organizations became interested and wanted to order a bicycle with different functions. De Zon, a daycare firm was interested in exploring whether a cycle would be suitable for transporting children. The decision to develop a daycare version can be explained by the entrepreneurs' opportunistic behavior in generating short-term revenues, as well as interest in exploring a diversity of markets.

Shift to city services (iteration #5)
The shift to the pick-up version can be explained by the involvement of the Province of Leeuwarden, who was interested in using Vrachtfeits for city services, such as park maintenance. Similar to the daycare application, it can also be partly explained by the opportunistic behavior of the founders in attempt to generate short-term revenues and find promising PM combinations.

Chapter 7

Cross-Case Analysis

The previous chapter presented innovation histories of the four case firms with a focus on the design experiments and stakeholder interactions the firms engaged in over time, and how their outcomes influenced the evolution of product-market (PM) combinations. This chapter presents a cross-case analysis of the case firms based on the variables of the conceptual model proposed in Chapter 5. The cross-case analysis will primarily compare similarities and differences among the case firms in order to address the following research questions:

- What patterns of product innovation processes can be identified? (RQ 2b)
- What explains the similarities and differences in patterns of product innovation processes? (RQ 2c)
- How does sustainability motivation influence the decision-making process, in particular the definition of product-market combinations? (RQ 3b)
- How does sustainability motivation evolve over time? (RQ 3c)

In the cross-case analysis, the role of explanatory constructs were analyzed and compared (7.1). Subsequently, the product innovation processes of the case firms were compared in respect to the variables of the descriptive model: PM iterations and design experiments, as well as stakeholder interactions to characterize the product innovation process in new ventures (7.2). Finally, based on this analysis, the propositions proposed in Chapter 5 are tested (7.3).

7.1. COMPARISON OF EXPLANATORY CONSTRUCTS

In Chapter 5, a conceptual model was proposed in order to describe and explain the product innovation process of new ventures. The model includes a number of factors that are likely to explain the similarities and differences among new ventures. The constructs specified in section 5.3 include: the type of opportunity, the perception of uncertainty, the entrepreneurial expertise, the resource position of the firms and the sustainability motivation of the entrepreneurs. In this section, the case firms are analyzed and compared along these explanatory constructs, in order to validate the conceptual model.

7.1.1. Type of opportunity

The conceptual model presented in Chapter 5, suggests that the type of opportunity is likely to influence the innovation process, in particular the type of action that drives the definition of PM goals. The opportunities vary depending on the degree of uncertainty linked to the supply (technological uncertainty) and demand side (market uncertainty) of an opportunity, i.e. whether the supply and/or demand side exist in an obvious manner (Sarasvathy et al., 2010). Since this study focuses on radical innovation from a micro perspective, i.e. products that significantly depart from existing products (refer to section 2.2.3), it is assumed that firms are confronted with high levels of uncertainty on both the supply and demand side.

From a demand side view, all of the case firms were dealing with new markets. The type of the products that the firms aimed to offer has not been previously available in the respective markets, thus the potential customers' familiarity with these products was low. Similarly, from a supply side, all case firms have engaged in products new to the firms. Nevertheless, uncertainties related to the supply side differ among the case firms due to the newness of the technologies to the firms and their respective industries. It is possible to order the cases based on the level of technological uncertainties, from high to low, as follows: Solar Dew, Sustainable Dance Club, Evening Breeze and Vrachtfiets. As an indicator of the newness of technology, Solar Dew has filed three different patents throughout the process and at the time was preparing to file a fourth one. Sustainable Dance Club and Evening Breeze filed one patent for their technologies, and Vrachtfiets none, as presented in the case description in Chapter 6.

The analysis of the case firms suggests that the majority of PM shifts were triggered by stakeholder interactions with or without commitment. While in some cases these shifts were the result of actual commitments, in some cases only the positive feedback of potential customers was sufficient to shift PM combinations (Table 7.1). Besides this, it was observed in the analysis that design experiments have both direct and indirect effects on the evolution of PM goals. While direct effects result in shifts in terms of applications and target markets, indirect effects have an influence on the self-selection process of stakeholders, which in some cases result in actual commitments, leading to a PM iteration.

In six iterations across the ventures, the negative or mixed outcome of the design experiments was seen as the trigger for a shift. Below are the iterations from Solar Dew (i.e. iteration #1, 4, 5 and 6), Evening Breeze (iteration #1) and Sustainable Dance Club (iteration #2). In most cases, the negative or mixed outcome of design experiments caused firms to shift to a new application. These negative or mixed outcomes are also described alongside the shift for each iteration.

Solar Dew

- From the irrigation mat to the gutter system (iteration #1): the low level of water production for irrigation, and the difficulty of producing the mat.
- From the gutter system to the solar dew dropper (iteration #4): the difficulty of using the membrane in a large-scale application, and the properties of the membrane (i.e. high quality of water but not in high quantities).
- From the Solar Dew dropper to the black top collector (iteration #5): the lessons from previous design experiments (i.e. irrigation mat concept). The black top collector was designed to evaporate downward like in the irrigation mat concept, in order to protect it from the wind and dust and increase the chances of catching sunlight, thus allowing higher quantities of water production.
- From the black top collector to the flex-bag (iteration #6): the low level of water production and the cost price of the product was not affordable for the target market.

Evening Breeze

- From four-poster to stand-alone (iteration #1): the dissatisfaction with the rigid ventilation system.

Sustainable Dance Club

- From clubs to various market segments (iteration #2): the low level of electricity produced through dancing (i.e. powering clubs even partly was not technically feasible).

Table 7.1. The triggers for the PM iterations of case firms

Iteration	Solar Dew	Sustainable Dance Club	Evening Breeze	Vrachtfiets
1	Design experiments Positive feedback of potential customers	Feedback of potential customers (no commitments)	Commitments to investors Positive feedback of potential customers Design experiments	Commitments to customer
2	Design experiments (indirect) Commitments to customer and investors	Feedback of potential customers (no commitments) Commitments to potential customers Design experiments	Negative feedback of potential customers (due to financial crises)	Commitments to customers Design experiments (indirect)
3	Design experiments	Feedback of potential customers (no commitments) Commitments to potential customers	Feedback of current customers	Commitments to customers Design experiments (indirect)
4	Design experiments			Commitments to customers Design experiments (indirect)
5	Design experiments			Commitments to customers
6	Design experiments			

Besides their direct influence, design experiments also have an influence on the self-selection process of stakeholders, which in some cases have resulted in actual commitments. This influence was observed in three cases. The first one was in the case of Solar Dew for two of their iterations. The shift from agriculture to industrial applications (iteration #2) was due to the commitment given to Shell. Within this process, the demonstrations (although with mixed outcomes) and the potential of the technology triggered Shell to approach Solar Dew with a request to develop an industrial application. Similarly, the self-selection process of investors in 2006 (iteration #5), and the shift to another concept was enabled through previous design experiments, which were proven in part, to be successful. Another case where design experiments led to stakeholder commitments is Sustainable Dance Club (iteration #2). Although the initial prototype was not successful in demonstrating how a dance floor could produce energy through dancing, this resulted various parties approaching Sustainable Dance Club. For instance, the collaboration with Absolute Vodka led to the development of some complementary concepts for the dance floor. Furthermore, various event and marketing firms started contacting Sustainable Dance Club to rent the floor; and as a result, in some cases providing feedback on the design of the floor. As soon as an early version was developed, Sustainable Dance Club started making business with those firms, resulting in actual commitments. Lastly, in the case of Vrachtfiets, as soon as a first prototype was developed, a number of organizations were self-selecting themselves with different requirements. These were the Municipality of Delft, which led to the development of parcel delivery concept; the Province of Leeuwarden, which led to the development of city service bike; and de Zon, which led to the development of a daycare concept.

In summary, besides the design optimizations and redesigns, design experiments have both a direct and indirect effect on the evolution of PM goals. First of all, the negative or mixed outcome of design experiments might be the trigger for the development of new applications or shifts to alternative markets. In this process, the positive feedback of potential customers is an important reinforcing factor. Furthermore, design experiments influence the self-selection process of the stakeholders, which in some cases result in actual commitments and shifts in product concepts and target markets. As a result, design experiments have an indirect effect on the evolution of goals by stimulation of self-selection process.

In addition, a high level of technological uncertainty appears to increase the degree of deviation from the initial PM iterations and the number of product iterations a firm engages. In this regard, the PM definition of Solar Dew has gone through several radical iterations (e.g. the irrigation mat, the gutter system, the flat collectors, the waterhouse and the flex-bag for a diversity of markets). By contrast, the definition of the product concepts for other three case firms have been evolving more smoothly. In conclusion, the type of opportunity, in particular the technological uncertainties, has influenced the innovation process in two ways: 1) the type of opportunity appears to influence the type of action that drives the evolution of PM definition, and 2) a high level of technological uncertainty appears to increase the degree of deviation from the initial PM combination.

7.1.2. Entrepreneurial expertise

The conceptual framework suggests that the level of expertise of entrepreneurs influences the innovation process in new ventures, primarily the number and duration of PM iterations a firm engages in over time. The team composition of case firms differs considerably in terms of entrepreneurial and business expertise across the cases, and over time per each case (Table 7.2 and Figure 7.1).

*Table 7.2. The level of expertise**

Case Firm	Expertise (entrepreneurial, business, industry)				
Solar Dew	**Low:** Corporate research director with managerial experience (1998-2000)	**High:** Two entrepreneurs with prior venture and managerial experience (2000-2004)	**Low:** Corporate manager with prior managerial experience (2004-2005)	**High:** One entrepreneur with prior venture and managerial experience (2006-2008)	**Low:** One water development expert with industry experience and one industrial design engineer with almost no experience (fresh graduate) (2008-present)
Sustainable Dance Club	**High:** Founder with venture experience (2005-2008)		**High:** Entrepreneur with venture and managerial experience (2008-present)		
Evening Breeze	**Low:** Founders with industry and some managerial experience (2001-2003)		**Low:** Two industrial design engineers, one with some venture experience; one with almost no experience (fresh graduates) (2006-present)		
Vrachtfiets	**Low:** Two industrial design engineers with almost no experience (fresh graduates) (2007-2013)				

In the early phases, before the firm foundation, the only firm that was managed by an expert entrepreneur was Sustainable Dance Club. In this period, although Sustainable Dance Club had been focusing on a specific market, the firm was flexible with the definition of the product. A number of various product concepts were affordably developed and tested in demonstration projects. In addition, although Sustainable Dance Club focused on the clubbing market, the firm engaged in a series of interactions with a number of potential customers, such as fitness clubs and energy companies, in order to partner for the co-development of the dance floor idea. The other three case firms were managed by novice entrepreneurs, namely a corporate research director (Solar Dew), two eco-consultants

** The ratings of the founders' and managers' entrepreneurial expertise is based on the assessment of the degree of prior venture experience as high' and 'low'. Although corporate managers have business experience, their entrepreneurial experience rated as low as they are expected to use predominantly causal (Sarasvathy & Dew, 2013). Furthermore, the novice designers are expected to predominantly use a causal logic considering the tools and approaches taught in design schools, e.g. the Faculty of Industrial Design Engineering; as such, their expertise is rated as low.*

(Evening Breeze) and two Industrial Design Engineers (Vrachtfiets). All of these three case firms appear to have focused on a particular PM pair before firm foundation. In the early phase, Solar Dew put its efforts into the development of an irrigation mat for agro-businesses and initially developed a proof of concept in a lab trial as well as a working prototype, which was later tested in a field trial. Evening Breeze focused on the development of a proof of concept for an air-conditioning bed for eco-resorts, in order to test the technical feasibility of the concept. Similarly, Vrachtfiets focused on the development of a cargo-bike conceptually and wrote a business plan in the early phases. The low level of entrepreneurial expertise appears to explain the early focus of novice entrepreneurs on specific PM combinations.

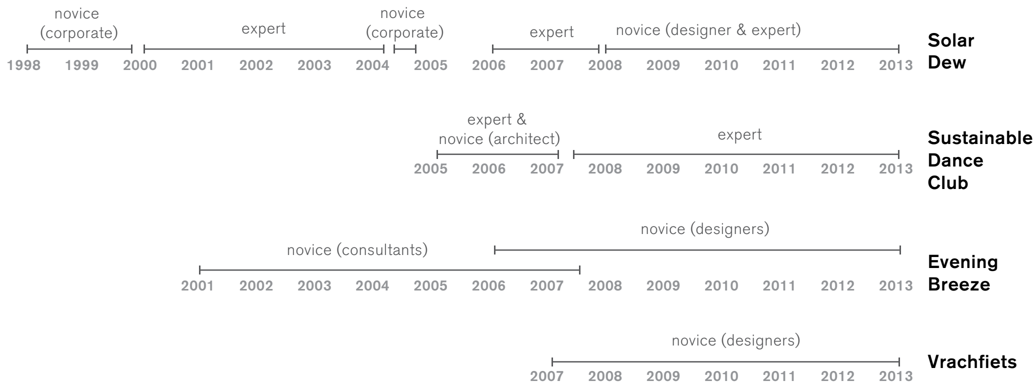


Figure 7.1. Team composition over time

After the firms were founded, the entrepreneurs of Solar Dew, Sustainable Dance Club and Evening Breeze were changing. In the case of Solar Dew, expert entrepreneurs were in charge. This appears to partly explain the engagement of the firm in a number of short-term PM iterations between 2000-2004. As one of the entrepreneurs re-calls in an interview in 2012: *"All this (the demonstration project with the launching customer) was the second line. It was actually the main activity we did, but it was not the main priority of what we were trying to achieve. What we were trying to achieve was drinking water for solar rich rural areas, where people are far away from where you have mass markets. What we tried to find is 'what are the product-market combinations that could make these technologies' and 'how do we make prototypes for that'?"* The most significant of these short-term PM iterations were the flat collectors concept for military, thermo dew for industrial applications and waterhouse for irrigation. Similarly, in the case of Sustainable Dance Club, an expert entrepreneur had taken over the firm after it was founded. In the first year after foundation, the firm was conducting a number of design experiments for various product concepts, and subsequently decided to focus on the development of the dance floor. From here they started interacting with a number of potential customers from a variety of markets such as event organizers, large brands, creative agencies, museums and others. Furthermore, as of

2011, the firm has been engaging with the development of an energy floor, and interacting with potential clients from a number of market segments. Therefore, a high level of entrepreneurial expertise appears to partly explain why some firms are more flexible with the definition of the PM pair.

On the contrary, in the case of Evening Breeze, two novice entrepreneurs (2006-present) were managing the company. In this period, the firm focused on a specific PM pair. Between 2006 and 2008, the firm put its efforts into the development of a four-poster bed for eco-resorts, and between 2008 and 2010 their efforts were put into the development of a stand–alone version. In this later period, the focus was shifting towards a high-end consumer market. Similarly, in the periods between 2004-2005 and 2006-2013, Solar Dew had also been focusing on specific PM pairs. When the corporate manager from Akzo Nobel took over the management of Solar Dew in 2004, he decided to narrow the scope and focus on the development of a household drinking water application for the bottom of the pyramid (BoP) market. A working prototype was developed and tested in Pakistan and Iran. Moreover, since 2008, the firm has been managed by a land and water development expert and an industrial design engineer. Within this period, the team continued to focus on the same application and target market. Therefore, a low level of entrepreneurial expertise appears to partly explain the focused commitments of firms' on specific product concepts and target segments.

In conclusion, the cross-case analysis suggests that the degree of entrepreneurial expertise influences the innovation process. Entrepreneurs with a low level of expertise appear to commit to a specific PM pair earlier in the process, in comparison to entrepreneurs with a high level of expertise. Consequently, this results in a lower number of product concepts and market segments that a firm engages in, as well as a longer duration of PM combinations and design experiments in the form of proof of concepts and working prototypes. On the contrary, expert entrepreneurs, appear to engage in a higher number of product concepts and market segments, shorter duration of PM combinations (some of which are dead-ends), and more affordable short-term design experiments.

7.1.3. Resource position

In the conceptual framework, resources, particularly financial resources, were introduced as a factor in partly explaining the differences in patterns of PM iterations among case firms. It was suggested that the availability of resources is likely to result in a lower number of long-term PM iterations in firms managed by novices, in comparison to firms managed by expert entrepreneurs. The availability of financial resources to the case firms varies considerably in terms of the type (personal resources, subsidy, investors, revenues, bank) and amount throughout the innovation process (Figure 7.2).

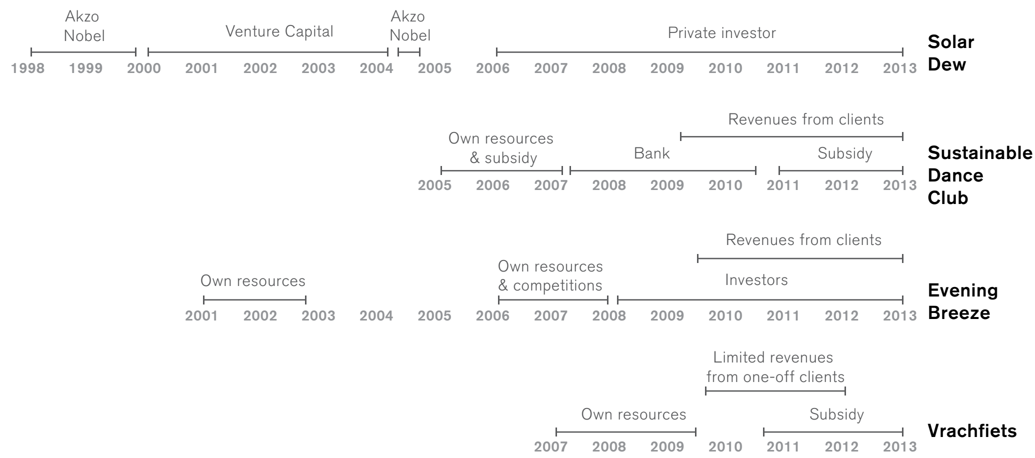


Figure 7.2. Financial resources

The periods that were managed by expert entrepreneurs show a higher number of short-term PM iterations, even though resources became available during the process. In the early phase, Sustainable Dance Club received a government grant, which was given to non-profit organizations developing projects related to sustainable development in the national and international context. This grant was used to explore various product concepts through affordable design experiments for a particular market. In parallel, the firm engaged in various market segments (e.g. energy companies and fitness clubs) that the dance floor idea could be applicable. In this early phase, various short-term PM combinations were explored. Soon after the firm was founded in 2008, a bank loan was received which enabled the realization of the first version of the dance floor, as well as a demonstration project with a launching customer. Even though the firm had initially focused on the development of the floor, various market segments (e.g. event organizations, museums) were probed at the same time. The firm began to generate revenues as of 2009, and breakeven was achieved in 2011. In addition to this at the end of 2010, the firm received EU funding for the development of the energy floor. Although the focus was on the development of the energy floor, since 2010 the firm has been exploring various market segments where the energy floor would be applicable, such as stadiums, airports, and city squares. Similar to Sustainable Dance Club, Solar Dew also engaged in various short-term PM combinations between 2000-2004, even though resources were available for the development of a particular product concept in a demonstration project. Solar Dew primarily derived revenue from the private investors of Business Factory between 2000 and 2003, and from Akzo Nobel between 2003 and 2005.

By contrast, access to financial resources was stimulating a more focused pattern of PM development for periods that were managed by novice entrepreneurs. In the case of Solar Dew, this is evident for two periods, i.e. when the project started within Akzo Nobel in 1998, and when the firm was taken over in 2006. In the early phase, the slack resources appear to partly explain the focused development of the irrigation mat concept, and the realization of costly initial design experiments of Solar Dew in the short-term. In this period, Solar Dew was managed by a corporate research director, whose entrepreneurial expertise was rated as low in the previous section. Similarly, when resources became available through a private investor, the focus was given to the development of a household water application for emerging markets in the period between 2006 and 2013. Although during this period the firm was initially managed by an expert entrepreneur, since 2008 the firm has been managed by novice entrepreneurs. Different to this, Evening Breeze and Vrachtfiets both started as projects in resource scarce environments. Both firms were able to use personal resources in order to conduct initial design experiments and develop product ideas conceptually with a focus on particular markets. Although these two cases initially possessed limited resources, they appear to have engaged in longer term PM combinations. Initially, Evening Breeze was not able to attract large amounts of financial resources in the form of a bank loan or investor funding; however, the firm deployed personal resources and competitions for conducting the subsequent design experiments. In addition, the initial prototypes in 2006 and 2007 were built in collaboration with suppliers who provided the cooling unit and ventilation system free of charge. The founders of the idea, Tim van den Brink and Nico Visser, partly supported the development from a financial, knowledge and network point of view. Subsequent prototypes and demonstration projects were mainly financed by competitions that Evening Breeze won during the period of 2007 and 2008. A working prototype and demonstration projects with positive feedback from potential clients were considered as a necessity in order to attract investors for further development, and partly explain the firm's commitment to the air-conditioning bed concept. Furthermore, the availability of investor funding from 2008 onwards appears to partly explain the focused development of an air-conditioning bed for the consumer market between 2008 and 2010. In early 2008, an early version of the concept was developed and in 2010 the current version was developed. Since 2009, the firm has put its efforts primarily in sales within the consumer market, and since 2011 within the hospitality market. In 2010, the main revenues were gained through the sales from the consumer market, and between 2011-2013 from the hospitality market. The firm has been an independent company since 2008, break even was achieved in 2010, and as of 2011, the growth is financed through a venture capital firm.

Similar to Evening Breeze, Vrachtfiets focused on a particular PM combination during the initial years before firm foundation; however, the firm eventually engaged in a more iterative PM development between 2010 and 2012. During this period, Vrachtfiets explored various target markets and generated revenues throughout 2010 and 2011 from on demand sales to a number of customers from a diversity of markets such as tourism, parcel delivery and daycare. It can be argued that this decision was due to the scarcity of personal resources for further development, and consequently due to the opportunities for short-term revenue generation. In this period, early versions in the form of commercial prototypes were developed. Furthermore, in 2011, the firm engaged in a long-term project in order to receive a government grant focusing on sustainability, innovation and international business. This appears to explain the firm's commitment throughout 2012 to the development of an

application that combines public transportation with tourism. Additionally, the government grant coincided with the firm's change in strategy, from exploring a diversity of PM combinations to a focus on only two applications (i.e. the cargo and pick-up cycles).
In addition, the availability of resources appears to influence the firms' ability to conduct design experiments. All firms started as projects in resource scarce environments except Solar Dew, which started in a large multinational company. The firm was able to realize costly design experiments within the time frame of a year. In contrast to Solar Dew, Evening Breeze had scarce resources; however, the firm was able to conduct their initial design experiments by making use of personal resources. These initial experiments were affordable prototypes constructed in order to test the technical feasibility, demonstrate the main functionality of the idea, attract potential customers within the target market and convince investors. Similarly, both Sustainable Dance Club and Vrachtfiets possessed limited resources; however, both firms developed their product ideas conceptually, and sought external resources to conduct initial design experiments. The dependence on external resources appears to explain the relatively late timing of initial design experiments.

In conclusion, financial resources appear to influence the innovation process in two ways. Firstly, the resources that became available during the process appear to stimulate a focused approach to PM development, with longer duration of PM combinations for firms managed by novice entrepreneurs. Secondly, the resource scarcity and dependence on external sources of funding appear to influence the timing and type of initial design experiments carried out.

7.1.4. Perceived level of uncertainty

The conceptual model suggests that the firms' perception of uncertainty is likely to influence the type of logic used by entrepreneurs, and is consequently likely to influence the PM iterations a firm engages in over time, as well as decisions concerning subsequent actions (i.e. design experiments and stakeholder interactions). The perceived level of market and technological uncertainty varies between the case firms and the different phases of the business development process. The case firms' perception of market uncertainty changed based on the feedback and commitment received from potential customers and other stakeholders. Furthermore, the case firms' perception of technological uncertainty had changed based on the outcome of design experiments. In the following paragraphs, the firms' perceptions of uncertainty over time are compared, and its influence on the innovation process is discussed.

Perceived market uncertainty
Since the beginning of the project until the involvement of Business Factory at the end of 1999, Solar Dew's perception of market uncertainty regarding the irrigation mat idea appear to be low. Akzo Nobel had a customer base in agriculture that provided nutrients to a number of agro-businesses. Therefore, the team assumed that once the product idea worked from a technical point of view, there would be readily available customers. As a result, it can be argued that the low level of perceived market uncertainty partly explains Solar

Dew's focus on agro-businesses between the period of 1998 and 2000. This resulted in a lab trial in the Netherlands and a field trial in Yemen, which provided positive feedback from agro-businesses, thereby reducing the team's perception of market uncertainty. As Potter, the entrepreneur and product manager of Solar Dew between 2000-2008 recalls in an interview in July 2012: "*There was a letter from a high-ranking official of the court of Jordan saying 'we heard you have had trials in Yemen, can you please come back and repeat these trials in Jordan, because we need this water?' People in Yemen were highly enthusiastic about a company coming in, putting a black piece of plastic down there, and water coming up, being pure as it is. The only problem was, it was not enough to justify the costs, but they wanted it. They wanted Akzo Nobel to find a solution, to increase the level of water.*" Similarly, Evening Breeze and Sustainable Dance Club had been presenting their business ideas early on to potential customers, and receiving positive feedback even before the development of the products. For instance, the idea of a sustainable dance club and floor had attracted enormous attention since the beginning; besides media attention, the firm received various requests from a number of organizations. As Smit, the co-founder of Sustainable Dance Club recalls in an interview in April 2014: "*What already cool was; there was already the market… So there was nothing, there was only a movie and sketches and people already started calling 'we want to buy the floor, we want to see the floor'. We had to, sort of, temper the enthusiasm… There were so many different requests; everybody wanted to do something. Either design with us or develop a different product. Most people were interested in the floor for their own venue or events or even business.*" By contrast, Vrachtfiets' interaction with potential customers was limited in the early phases; however, the team had a network among students and student organizations, and had been receiving positive feedback from other stakeholders, such as the incubator in Delft and the mentors within the Faculty of Industrial Design Engineering. This positive early feedback, before the development of a working prototype, lowered the team's perception of market uncertainty to a certain extent. Such feedback also appears to have influenced the firm's focus on a specific product idea and/or target market early in the process.

Furthermore, while Vrachtfiets and Evening Breeze's perception of market uncertainty was fluctuating smoothly, Solar Dew and Sustainable Dance Club's perception fluctuated more radically over time. With the involvement of a venture capital firm in 1999, both the team's and potential investors' perception of market uncertainty appears to be high. The investors were concerned about the business feasibility of the project without a patent and a launching customer. In the beginning of 2000, with the involvement of Shell, the perceived market uncertainty of the investors within Business Factory was lowered. This led to a series of design experiments with Shell, focusing on wastewater reduction; however, the team's perception of uncertainty was still high. As Potter recalls: "*In those days we were not sure what the scope of the technology was. Could there be other product-market combinations? So we had different product-market combination experiments on the side.*" Solar Dew's perception of market uncertainty had lowered in 2006, with the involvement of a private investor who considered the readily available customers in China, as well as the BoP market. On the other hand, Sustainable Dance Club has started to receive negative feedback from clubs, which were then reluctant to buy the dance floor. The clubbing market was not taking off, and other customers were showing interest in renting the floor. Although the team continued to put their efforts into the clubbing market, and engaged in a number of design experiments for different product concepts, eventually the high levels of market uncertainty in the clubbing market led to a shift to alternative markets, decreasing the team's perception of market uncertainty.

On the other hand, Vrachtfiets and Evening Breeze's perception of market uncertainty was fluctuating more smoothly. The eco-resorts were in general positive with the idea of an air-conditioning that cools only the bed space. In that sense, the team's perception of market uncertainty appears to be low, and it was just a matter of developing the product; however, the attention received in the Dutch consumer market throughout 2007 and 2008 was shifting Evening Breeze's focus into a different market. The team considered the consumer market as a 'safer' option considering the positive feedback, proximity and cultural reasons. Furthermore, the reluctance of bed manufacturers in buying the EB cooling system resulted in a higher degree of perceived market uncertainty in late 2010, and consequently a shift into the initial target market. On the other hand, although Vrachtfiets had been engaging with a number of potential customers and generating revenues from one-off projects, the team's perception of market uncertainty appears to have gradually increased during the process. The firm was not able to grow in a specific market segment and identify a promising PM combination. This partly explains their engagement in a variety of markets until a government grant was received in 2011.

Perceived technological uncertainty

The perception of technological uncertainty varies between the case firms and the different phases of the process. Solar Dew appears to have higher levels of perceived technological uncertainty compared to Sustainable Dance Club, Evening Breeze and Vrachtfiets. Solar Dew's high level of perceived technological uncertainty stems from the difficulty of developing an application based on a technology developed in their R&D laboratory. On the other hand, Sustainable Dance Club, Evening Breeze and Vrachtfiets perceived lower levels of technological uncertainty before the design experiments. The use of mainly existing technologies within the products, as well as the optimism of the founders, might explain the low level of perception. For instance, as Geerinckx, the co-founder of Vrachtfiets recalls in an interview in May 2010: *"We had a lot of ideas about the Vrachtfiets, and we thought it would be easy to just design one because we thought it is just a bicycle with 4 wheels. Looking back, that was a big mistake."* Furthermore, as van Doorn, the co-initiator of Sustainable Dance Club recalls: *"I am always optimistic. At that time, at the end of 2005, I thought that half way through 2006 we are going to have a floor. That was very naive of course."* The low level of technological uncertainty appears to partly explain the firms' relatively late engagement with high fidelity prototypes.

Besides the varying degrees of initial perceptions, the case firms' perception of technological uncertainty throughout the process fluctuates based upon the outcome of design experiments. Although initial 'proof of principle' experiments resulted in positive outcomes for Evening Breeze, they resulted in mixed outcomes for Solar Dew, Sustainable Dance Club and Vrachtfiets. Evening Breeze was successfully able to conduct two design experiments in 2001 and 2002, and proved that the principle works. Despite the positive outcome of these experiments, the team's perception of technological uncertainty was getting higher due to a lack of technical skills for further development, which explains the decline in the speed of development. The high level of perception was lowered with the involvement of industrial designers in 2006, who could further engage in a series of design experiments with positive outcomes. For Sustainable Dance Club, with an initial prototype the team was unable to work on the details of technology. As, van Doorn recalls in an interview in April 2014:*"At that time I had some ideas of how it could work. I was thinking of the human powered flashlight. I was thinking it could work like that. I studied architecture. I learned some engineering but the rest was of course common sense. Then our contact from Delft University of Technology came up with the idea of piezo technology, which was underdeveloped at that time. In the end piezo did not work. In the end it is like a human powered torch in combination with software to stir lights."* The outcome of the initial design experiments and the team's realization that the lack of technological knowledge in translating human movement into energy, increased the Sustainable Dance Club' perception of technical uncertainty. As a result, technical experts were sought to translate the dance floor concept into a working prototype, which then lowered the perception of their technological uncertainty to a certain extent. Following this working prototype, a first series of dance floor was developed within a year, thus lowering perceived technological uncertainty further. Similarly, Vrachtfiets' initial prototype has resulted in mixed outcomes. There were technical flaws particularly due to the long chain the bike required. Instead of hiring experts like Sustainable Dance Club, Vrachtfiets chose to work closely with suppliers to build Vrachtfiets on demand. Vrachtfiets then engaged in one-off projects; based on the request of a variety of early customers, in order to decrease the technical uncertainty. Finally, for Solar Dew, with the involvement of the venture capital firm at the end of 1999, the team's perception of uncertainty appears to have increased. Firstly, the field trial in Yemen offered mixed outcomes, i.e. the principle worked, but producing the mat was difficult and the quantity of water produced was not as high as expected. The team considered that the product might not produce the expected amounts of water, and as a result, would not justify the use of expensive thick plastic that was necessary for a product lifetime of three years. This stimulated the team to think of other applications based on the membrane technology, which may partly explain the short-term PM combinations the firm engaged in between 2000 and 2004. Moreover, the outcome of subsequent trials proved that developing applications based on the polymer was difficult from a production, cost and water output perspective. In 2006, when a private investor bought the patent, he thought they had a proven technology and it was a matter of developing a product based on the membrane. They expected to be in the market within the time frame of one year, as Croon, the investor of Solar Dew from 2006 on, recalls: *"We thought at that moment it was about a year to go before it was ready for the market. We learned that it was much longer during this period. And we learned that we had to go for a totally new start."* Hence, it can be argued that the low level of perceived technical uncertainty of the investors and the team at least partly explains the focused development of two product concepts between 2006 and 2009, and a number of costly design experiments.

Between 2008-2009, Solar Dew worked on the details of the product design and the production system. In 2009, the membrane unexpectedly failed in a long-term test; however, instead of abandoning the product or searching for alternative product concepts or target markets, the firm decided to continue and search for alternative membranes that could be used within the same product idea. As Kleij, the product manager of Solar Dew, recalls: *"There was no quick fix"*. They could not just buy another membrane from the shelf and apply it to their concept. As a result, since 2009 the team has put its efforts into the development of a membrane, which could be applied to the current product concept. Since this time, the team's perception of technological uncertainty appears to be high; this partly explains the firm's reluctance in engaging stakeholder interactions. As Kleij explains: *"The problem with BoP is that you are bringing in a new technology, but you are also bringing in a new business model. People are willing to test a new business model if you have a proven technology. They are not willing to work with an unproven technology because the risk is too high. The stage, which we are in right now, is very unclear in terms of results; and a lot of governments, NGOs do not like this phase. It is too risky. It is difficult to find subsidies in the area between a proven technology and a commercial technology. That is the place where the risk is."* Accordingly, the team has recently been searching for alternative markets where they do not have such cost limitations as in the case of the BoP market, although the vision of the company is to reach the BoP market.

In conclusion, the case comparison suggests that entrepreneurs' perception of market and technological uncertainty influence the innovation process. The perception of uncertainty primarily influences the duration and number of PM iterations. A high level of perceived market and/or technological uncertainty appears to increase the number of PM iterations, while decreasing their duration. Moreover, entrepreneurs' perception appears to influence the drivers and timing of design experiments and stakeholder interactions. Particularly, when entrepreneurs perceive a low level of technological uncertainty, they appear to postpone high fidelity design experiments. In cases of high level of technological uncertainty, they appear to postpone the stakeholder interactions.

7.1.5. Sustainability motivation

Sustainability motivation was introduced into the conceptual framework as it is linked to one of the main research questions of this study: the influence of sustainability motivation on the innovation process in new ventures. In the conceptual model, it was suggested that sustainability motivation is likely to influence the influence go/no go decisions, and a firm's commitment to a particular PM combination. In this paragraph, the sustainability motivation of entrepreneurs is compared on the basis of the degree of priority of social and/or environmental goals in comparison to financial goals, and the degree of change entrepreneurs aim to bring to a particular market and society (i.e. their market effect). The case firms vary in terms of the degree of change the entrepreneurs aim to bring to the market and society. On the other hand, they are similar in terms of the degree of prioritization of sustainability goals in the beginning of the process, since this was one of the case selection criteria of this study. For all firms in this case study, either environmental or social issues, or both, were core to the business goals in the beginning of the process. This is reflected in the firms' efforts in measuring the environmental sustainability of their products (through measurement tools such as Life Cycle Assessment and Eco-cost Value Ratio or energy calculations), as well as their choice of materials and substances with lower environmental impact. The degree of prioritization of sustainability goals however, appears to change throughout the innovation process based on the outcome of design experiments and stakeholder interactions. The following paragraphs describe how the innovation process of the case firms is influenced by the sustainability motivation of the entrepreneurs, as well as how the innovation process influences the degree of priority of social and/or environmental goals.

The influence of the degree of change the entrepreneurs aim to bring to a particular market
During the first years, Sustainable Dance Club had the ambition to bring a high degree of change to the clubbing market, which is reflected in both the firm's desire to create a worldwide network of sustainable clubs, as well as their effort in 2008 that was put into the exploration of franchising the Sustainable Dance Club internationally as a business model. Even the name of the company reflects this ambition and their focus on clubs. In this respect, Sustainable Dance Club started from a niche, i.e. parties and events, and from this they organized a number of demonstration projects in 2006 and 2007 with the aim of expanding to the clubbing market. Similarly, the founders of Evening Breeze were interested in the 'sustainabilisation' of tourism, and considered eco-resorts as a good starting point. This high ambition is reflected in a company document in 2006: *"By 2025 all tropical tourists enjoyed their holiday in the most sustainable way and slept comfortably in an AircoBed."* (the vision statement), and *"Evening Breeze will have to establish its role as a niche player in the industry. Competing with the air conditioning giants is hopeless. A prominent role as a sustainable air conditioning concept supplier to tropical tourist accommodations is possible. This position can be expanded towards a sustainable concept provider to tourist applications, or as a sustainable air conditioning concepts provider in many segments."* The cases of Sustainable Dance Club and Evening Breeze suggest a high degree of change that entrepreneurs aim to bring to a specific market, and appears to influence the long-term market ambition of the firms, i.e. starting from a niche and expanding to a mass market. Furthermore, both cases suggest that a high ambition to influence the mass markets is partly explained by the (longer) duration of the focus on the initial market segments, either in a niche or a mass market. In the case of Sustainable Dance Club, as a result of this high ambition, the firm appears to postpone the decision to shift to alternative target segments that were positively reacting. As van Doorn explains: *"We were too idealistic, focusing on the club owners instead of focusing on the floor."* In the case of Evening Breeze, it can also be argued that the long-term focus on eco-resorts was driven by the positive feedback of potential clients in the target market. Furthermore, the commitment to a particular market appears to increase the stakeholder interactions in the early phases.

Both Sustainable Dance Club and Evening Breeze were active in their target markets and aimed to attract potential clients from the beginning, before a specific product was even developed and not even in the form of a working prototype. Different than Evening Breeze, Sustainable Dance Club's ambition to influence the clubbing market appears to have caused the firm to adapt a more holistic approach to its target market. Consequently, this increased the number of product iterations the firm engaged in during the early years.

In contrast to this, Solar Dew and Vrachtfiets did not start with the ambition to make a particular market more sustainable. Instead, Solar Dew had the ambition to exploit the unique properties of a polymer for developing an affordable water application for solar rich areas. They initially started with agro-businesses and iterated in diverse markets in an attempt to find a promising PM combination. Similarly, Vrachtfiets started with the idea of offering an alternative sustainable solution to students in transporting voluminous goods for short distances and soon after focused on the cargo-bike concept, which could be applied in a diversity of markets. Having a focus on a specific technology or product appears to explain short-term focus on a range of target markets. In addition, it can also be argued that developing products that are applicable in a broad scope of markets eases the justification of the social or environmental claims for alternative market segments, consequently increasing the number of target segments a firm engages in over time. For Solar Dew and Vrachtfiets, it appears that developing products that could potentially replace existing products, e.g. a cargo-bike replacing motor vehicles, or a solar powered desalination device to replace expensive energy intensive water purification technologies, was easier, at the least in the entrepreneurs' mind, to justify that similar sustainability claims would also account for other markets. Similarly, Evening Breeze has been committed to a particular product idea since the beginning. Although the firm had a high ambition to change the hospitality market, the entrepreneurs were confronted by a shift to the consumer market. In this case as well, it can also be argued that developing a highly energy efficient air-conditioner that can replace existing air-conditioners was, at least in the entrepreneurs' mind, a justification for the shift from the hospitality to the consumer market. Furthermore, having focused on a specific technology or product (cases Vrachtfiets, Solar Dew and Evening Breeze) appears to have influenced the firms' urge to engage in design experiments in order to test the technical feasibility of product ideas. In this regard, while Solar Dew and Evening Breeze were able to conduct initial design experiments with available resources, Vrachtfiets relied on external resources and engaged in a series of stakeholder interactions in order to acquire resources for further product development.

The evolution and influence of sustainability issues as core business goals
The cases of Solar Dew and Sustainable Dance Club suggest that social and environmental issues as core business goals appears to lower the performance threshold and subsequently influence go/no-go decisions. This observation is in line with Berchicci (2005) who suggested that a high environmental ambition might be an important factor that can result in the escalation of the teams' commitment to a certain course of action, despite the clear signal suggesting otherwise. It can be assumed that the higher the degree of prioritization of

sustainability issues as core business goals, the lower the influence of the outcome of design experiments and stakeholder interactions on subsequent decisions. In these situations, the firms appear to ignore a negative outcome or feedback and follow their own preferences and ambitions. For instance, the sustainability motivation of Solar Dew appears to have influenced go/no-go decisions throughout the whole process, and as Potter recalls in an interview 2012: *"I think the benefits this offers, having non-fouling water production independent of the feed, if it can be made, it is too good to kill. I wouldn't be the one to kill this. All the suppliers that have collaborated in this are all special people. And they were all, this is where social motivation comes in, very sure business people, or technical people with a lot of professional pride and esteem, and they all risked that for this application for the similar reason … Because normally you would have cut this project several times. But all these people are also highly critical. So if it were their investment into something else they would have cut the project easily."* For Solar Dew, the most significant examples of this were at the beginning of the project, when the idea of an affordable desalination device was picked up by the Corporate Research Manager of Akzo Nobel in 1999, and when the membrane failed in 2009. In both cases, the team decided to conduct design experiments despite the high risks. Similarly, despite the positive feedback from other market segments in the first years, Sustainable Dance Club decided to continue with the clubbing market. As van Doorn recalls in an interview in April 2014: *"We were too idealistic, focusing on the club owners instead of focusing on the floor. So for us it was much more about creating sustainable clubs for the club owners. We had done a thorough analysis of the whole organization (a club) and how they could integrate sustainable purchasing in their organization. So the organizational aspect was very important and it really took a long time to accept that the floor was the thing. If we would have shifted earlier, maybe it would have been different."*

It was also observed that the level of resources, and the outcome of design experiments and stakeholder interactions influenced the sustainability motivation of the entrepreneurs. For instance, in the cases of firm survival and short-term opportunities to generate revenues for further development and growth, the firms appear to lower the degree of prioritization of sustainability as their business goals. This argument is line with Volery (2002), who suggests that the financial bottom line is still the most important bottom line. The Sustainable Dance Club case suggests that the realization of the challenge of selling to the clubs and achieving environmental goals for the dance floor (due to the limitations in human power and its translation into energy), as well as the positive feedback from other markets segments had an influence on the value proposition and the business model of the firm in 2009. As van Dongen, the co-founder of Sustainable Dance Club, recalls in an interview in 2010: *"A lot of plans to build new clubs were canceled because the renovation is relatively more expensive. I think that was an important factor; we saw that we could not sell, so the company went into the survival mode and rented out floors."* In this way, the firm was abandoning its emphasis on clubs and decreasing the clubs' environmental impact. They were focusing more on the social aspects and creating awareness in other market segments, i.e. a change in the focus from direct environmental savings to indirect effects, through making people aware of their environmental impact. In that sense, a number of complementary products were developed such as energy displays that show the crowd the amount of electricity they generate through dancing. Similarly, the challenge of reaching eco-resorts, as well as the positive feedback from the consumer market in the Netherlands was perceived by Evening Breeze as an opportunity for revenue creation for further development. The firm shifted its focus to a different market segment, where the energy saving potential of the product was significantly lower compared to tropical resorts (considering the number of days per year the product is being used, as well as the chances of selling a luxury product to consumers who previously did not own an air-conditioner). As suggested earlier, this decision is also appears to be influenced by the ease of justification of sustainability claims, at least in the entrepreneurs' mind, for the consumer market. In the case of Solar Dew, the technical challenge associated with the production and quantity of water produced, was a driver for the team to experiment in different markets such as military and industrial wastewater, where the social value of the product was lower compared to agriculture and BoP markets. Apparently, the sustainability motivation of entrepreneurs, in particular the relative importance of social, environmental and economical goals, varies over time. Although the firms put effort into balancing multiple objectives, as suggested by scholars in literature (e.g. Parrish, 2010; Schlange, 2007), the tradeoffs were inevitable (Hahn et al., 2010), and the entrepreneurs appear to have emphasized and de-emphasized different goals over time. An emphasis on social and/or environmental mission appears to have influenced go/no-go decisions, and escalate firms to commit to particular PM combinations. In addition, an emphasis on economical goals, whether due to survival issues or generating short-term profits, also appear to have influenced the firms' decision to shift to alternative PM combinations, or reformulate their value proposition in relation to sustainability. It was also observed that the emphasis on economic goals is, in some cases, temporary; firms focus on economic goals until the firm survival is no longer perceived as critical.

In conclusion, sustainability motivation appears to influence the innovation process in three ways: 1) a high degree of change that entrepreneurs aim to bring to a particular market appears to influence the long-term market ambitions of a firm, and lengthen the focus on the initial market; 2) a focus on a specific market versus their product appears to influence the justification of sustainability claims, and consequently the number of product and market iterations a firm engages in, as well as the type, timing drivers of design experimentations and stakeholder interactions; and 3) a high degree of prioritization of sustainability issues as core business goals appears to escalate the commitment of decision-makers, and influence go/no go decisions unless the firm survival is perceived as critical.

7.2. CHARACTERIZING THE INNOVATION PROCESS

7.2.1. Patterns of PM iterations

The descriptive model presented in Chapter 5 suggests that the innovation process of firms vary on the basis of the number and duration of PM iterations. This study has observed that while some firms appear to be more focused on a specific product idea and/or target market, others appear to be more flexible and iterative with their definition of the product and/or market. Furthermore, firms' behavior in terms of focused versus iterative changes over time. Figure 7.3 illustrates the engagement of firms in various product ideas and target markets over time. Based on the focus given to a product idea or target segment, five different patterns were observed (see Figure 7.4 and Table 7.3).

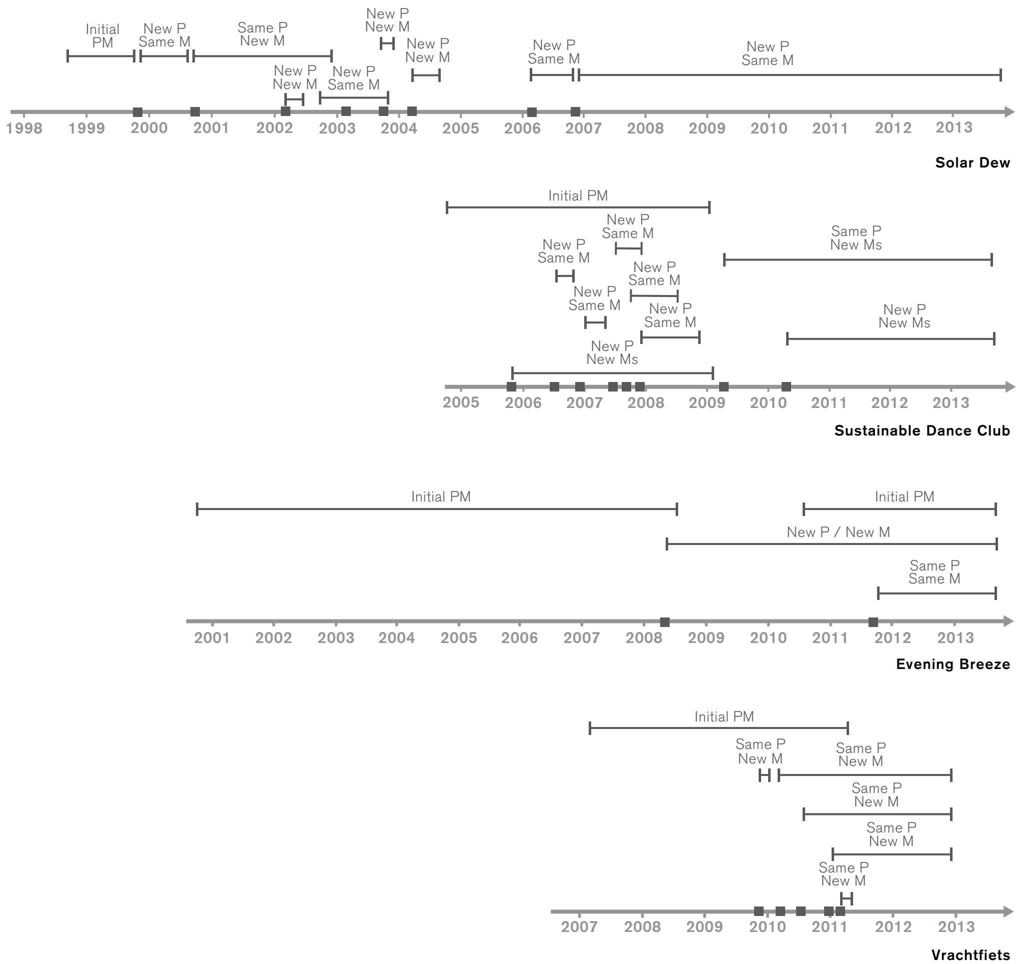


Figure 7.3. Overview of PM iterations

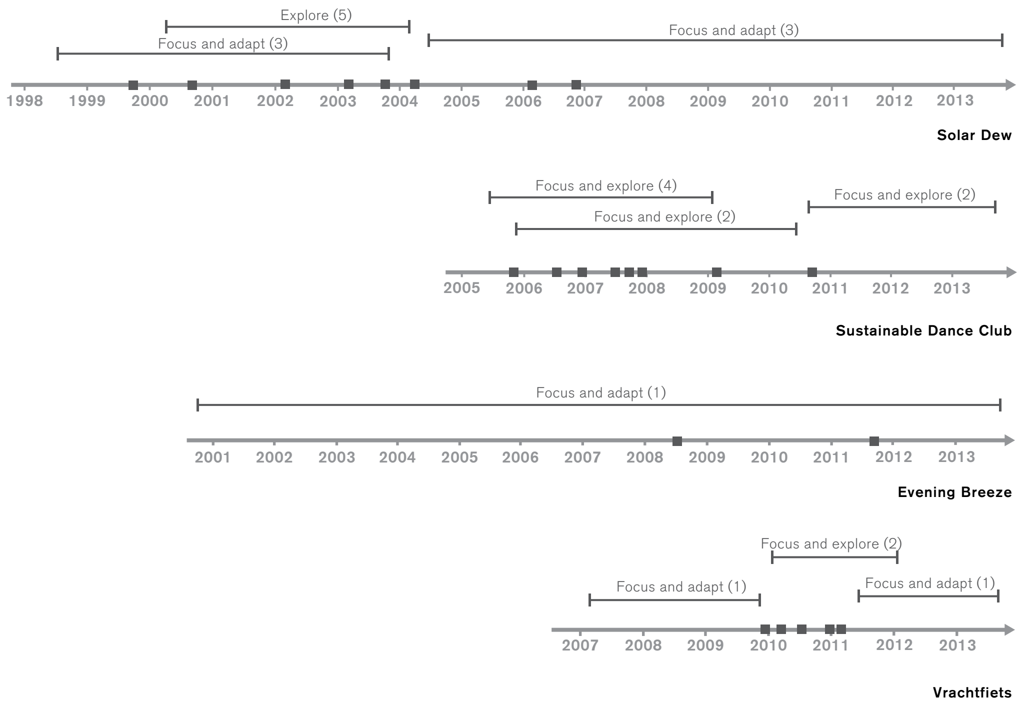


Figure 7.4. Patterns of PM iterations

Table 7.3. PM iterations

Case firm	Pattern	Period	Products	Markets
Solar Dew	Focus and adapt (3) Explore (5) Focus and adapt (3)	1998-2003 2000-2004 2004-2013	Three main product categories and its variations	Three main markets
Sustainable Dance Club	Focus and explore (4) Focus and explore (2) Focus and explore (2)	2005-2010 2005-2009 2010-2013	Five different products	Three main markets
Evening Breeze	Focus and adapt (1)	2001-2013	One main product category and its variations	Two main markets
Vrachtfiets	Focus and adapt (1) Focus and explore (2) Focus and adapt (1)	2007-2009 2010-2012 2011-2013	One main product concept and its variations	Three main markets

1. Focus on a specific P and shift M when necessary

Since the beginning, the focus of Evening Breeze was the development of an air-conditioning system. In 2008, the market focus shifted from hospitality to consumer due to proximity reasons and positive feedback they had received. The focus shifted back to eco-resorts in 2010, when the bed manufacturing market was declining, and further back to the hospitality again in 2011, on the basis of feedback from potential customers in the consumer market. The firm has put their efforts into the development of a specific product, shifted their market focus, and adapted the product concepts based on customer feedback. Likewise, since the beginning, Vractfiets had focused on the development of a cargo bike. The firm's initial intention was to start with the students in Delft by offering a rental service, and to generate revenues mainly from mobile advertisement. Both firms engaged in design experiments and stakeholder interactions to find out what their target customers want, and align to specific market requirements. In both cases, the product concepts were evolving smoothly based on the outcome of design experiments and stakeholder interactions. A focus on a particular product concept has resulted in a low number of long-term PM iterations in the respective periods for both case firms.

2. Focus on a specific P and explore alternative Ms

Vrachtfiets' innovation process between 2010-2012, as well as Sustainable Dance Club's development process between 2005-2009 and 2010-2013 shows a focused pattern of product development. However, both firms have been more flexible with the definition of target markets and have also explored a diversity of markets. For instance, Vrachtfiets engaged in at least five different markets such as parcel delivery, public transport and daycare. Similarly, with the realization of the dance floor as the flagship product, Sustainable Dance Club put its focus on the development of the floor in 2006. Although, the firm's main focus was on clubs between 2008 and 2009, due to the enormous attention the dance floor received, and the need for resources to develop the floor further, the firm probed to co-develop the dance floor idea with a number of potential clients between 2006-2009, such as energy companies and fitness clubs. Similarly, between 2010-2013, this time with the energy floor idea the firm interacted with a number of clients that could use the energy floor in a public space. While the ambition of Sustainable Dance Club between 2005-2009 was to acquire resources and find a business model that work, the ambition between 2010-2013 was to explore new markets based on a proven product concept. Likewise, during the period between 2010-2012, Vrachtfiets aimed to find a promising opportunity in a variety of markets and sell the product to generate revenues for further development. Although, during these periods, the shifts in target markets appear to be more radical compared to the first pattern, in this case too the product concepts were evolving smoothly. Furthermore, the number of PM iterations appears to be higher and their duration shorter compared to the first pattern.

3. Focus on a specific M and shift P when necessary

On the contrary, Solar Dew's innovation process between both 1998-2003 and 2004-2013 had a more focused pattern in terms of target markets. The firm was adopting product concepts based on the outcome of a number of design experiments. Between 1998 and 2000, the firm focused on agro-businesses and developed two concepts during this period, namely the irrigation mat and the gutter system, with the aim of water desalination and similar product requirements. Between 2000 and 2003, the firm focused on wastewater reduction and carried out a demonstration project with a launching customer. Based on the outcome of design experiments, the product concept changed from the gutter system to the Waterhouse concept. Finally, between 2004 and 2013, the focus of the firm was on the BoP market, and they developed three different concepts, i.e. Solar Dew Dropper, Black Top Collector and FlexBeg. In these periods, the combined effect of a strong focus on a specific market and the challenge of translating a technology into applications appears to bring about more radical shifts in terms of product concepts. Furthermore, similar to the first pattern, the number of PM iterations appears to be lower, while their duration is longer.

4. Focus on a specific M and explore alternative Ps

The early phases of Sustainable Dance Club's market development displays a focused pattern, i.e. targeting the clubs and exploring a number of product concepts within the same target segment. Different to Solar Dew's product development process (1998-2003 and 2004-2013), Sustainable Dance Club engaged in completely different product concepts, such as the dance floor, personal cup holder, SDC mini and sustainable bar. During this period, the focus on a particular market segment appears to bring about more radical shifts in terms of product concepts; however, different from the third pattern, being flexible with the definition of the product appears to increase the number of PM iterations while decreasing their duration.

5. Explore alternative Ps and Ms

In parallel to the focused development of a particular PM pair between 2000 and 2003, Solar Dew had been engaging in a number of product concepts and target markets between 2000-2004, such as the thermodew concept for industrial wastewater and the flat collectors for military. The ambition of the firm during this period was to explore new possible uses of the membrane technology in various product ideas and market segments. This explorative period resulted in radical shifts, both in terms of product concepts and target markets; consequently in a high number of short-term PM iterations.

In summary, the case study data suggests that the number and duration of PM iterations differ between the case firms, as well as throughout the innovation process. Five different patterns were recognized: (1) focus P (product) and adapt M (market), (2) focus P and explore Ms, (3) focus M and adapt P, (4) focus M and explore Ps, and (5) explore both Ms and Ps. 'Focus and adapt' (pattern 1 and 3) results in linear paths of development in an iterative fashion based on customer feedback and design experiments. It results in fewer number of PM iterations with longer durations, similar to a classic product development process. These patterns are characterized by convergent development with a focus on particular PM pairs and shifts necessitated by the process. On the contrary, 'focus and explore' (pattern 2 and 4) as well as 'explore' (pattern 5) result in a higher number of PM iterations with shorter durations. These patterns are characterized by divergent development in search of a promising PM combination.

7.2.2. Design experiments and stakeholder interactions

Both similar and different patterns of PM iterations have been discussed in the previous section. These similarities and differences are likely to result in different design experiments and stakeholder interactions. This section takes a closer look at the drivers, type and timing of design experiments and stakeholder interactions (see Figure 7.5 and 7.6 for an overview). The analysis will refer to the focused and explorative periods identified in the previous sections and the explanatory constructs discussed in section 6.2.

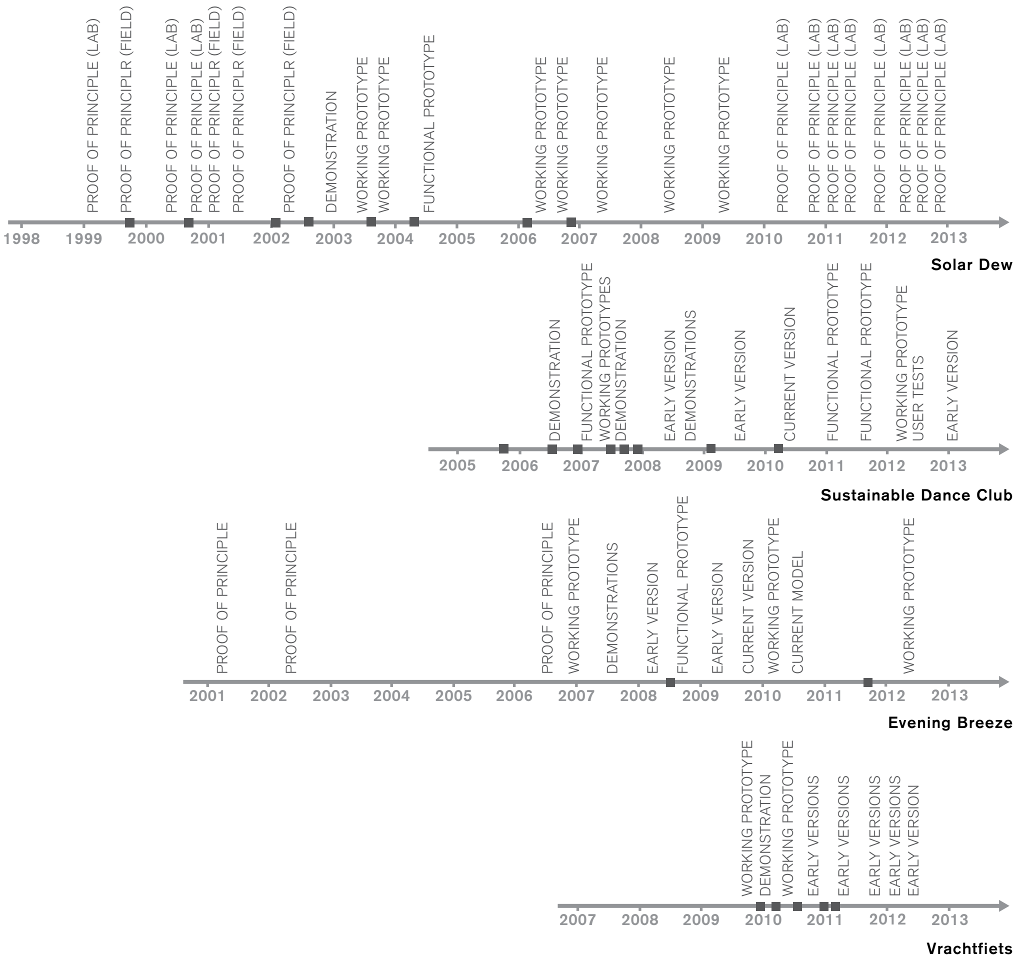


Figure 7.5. Overview of design experiments

In contrast to other firms, Sustainable Dance Club appears to have prioritized market development above early product development in the early years. The sustainability motivation of the founders appears to have influenced this focused pattern of market development. The early period of Sustainable Dance Club's innovation process is characterized by a number of short-term affordable design experiments, such as conceptual drawings, videos, and a number of design experiments conducted by modifying existing products and building low fidelity prototypes for different product ideas. The driver for conducting these design experiments appears to be the early external exposure of the business idea, and getting the commitment of stakeholders to develop the 'sustainable dance club' idea further. In that sense, these design experiments were instrumental in stimulating stakeholder interactions, getting their commitments and exploring new possibilities; rather than committing to a specific product idea or testing its feasibility. The firm has been intensively interacting with a diversity of stakeholders who could help develop the business idea further. The expertise of the entrepreneur appears to partly explain this explorative pattern of product development, the early stakeholder interactions, and the low fidelity design experiments the firm had conducted as soon as a limited amount of subsidy became available.

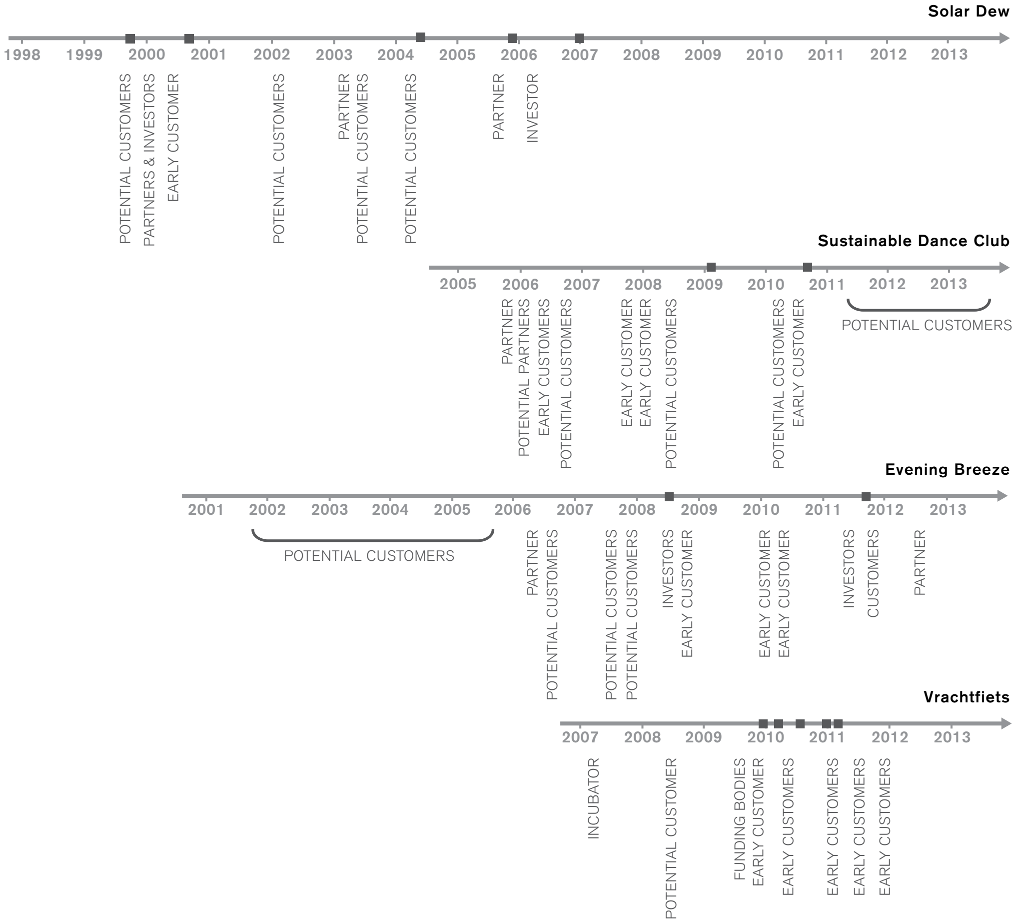


Figure 7.6. Overview of stakeholder interactions

On the contrary, the other three case firms have prioritized early product development over market development, which mirrors a causal logic. Accordingly, the initial design experimentation strategy strongly resembles a classic product development process. Departing from customer needs, the firms aimed to develop product concepts iteratively, based on customer feedback within their respective target markets. The initial actions taken by firms was to conduct a series of design experiments (i.e. a number of proof of concept prototypes and/or working prototypes), to initially test the technical feasibility and to demonstrate the functionality of a specific product idea with a target market in mind. These firms all had a focused pattern of product development, yet they realized the different design experiments within different time frames. While Solar Dew was able to conduct a series of design experiments as soon as the product idea was born, Evening Breeze had engaged in two affordable low fidelity prototypes, and Vractfiets was able to conduct a first design experiment only three years after the idea was born. Apparently, the ease of access to financial resources within Akzo Nobel enabled Solar Dew to take quick action and conduct expensive experiments (due to the skilled personnel and travel costs). Similarly, the personal resources of the founders of Evening Breeze enabled the realization of affordable initial prototypes. Vrachtfiets, however, relied on external resources and sought out subsidies. Furthermore, all three firms were interacting with external actors to a lesser extent in comparison to Sustainable Dance Club. The majority of these stakeholders were potential customers from the target market in order to get feedback and acquire resources for further development. During the early periods, all of the firms were managed by novice entrepreneurs, which appears to explain the focused pattern of product development.

Furthermore, the outcome of the initial design experiments and stakeholder interactions appears to partly explain the duration of the initial PM pair. Evening Breeze was successful in developing the air-conditioning bed idea iteratively throughout 2001 and 2008, based on the positive outcome of design experiments and market feedback; thus the firm's perception of uncertainty decreased during this period. Although there was a period of stagnation between 2003 and 2006, with the involvement of industrial design engineers in 2006, the firms were relatively fast to arrive at a working prototype, and in addition, conduct a number of demonstration projects by making use of the founders' personal resources and eventually attracting investors. As a result, the whole product innovation process of Evening Breeze shows a focused pattern of product development, and a shift to other market segments based upon stakeholder interactions.

On the other hand, the outcome of initial design experiments and stakeholder interactions have revealed mixed outcomes for Solar Dew, Vracthfiets and Sustainable Dance Club; thus increasing the firms' perception of uncertainty. In the case of Solar Dew, the mixed outcome of initial experiments led to a different concept for the same target market in 2000. During this period, the focus of the firm shifted to an alternative market in order to convince both investors and an early customer; this led to a demonstration project and provided the opportunity to develop the product idea further. The period between 2000 and 2003 was characterized by a series of design experiments in the form of proof of concepts, field trials with working prototypes and a large-scale demonstration project. Also in this period, the driver for design experiments was to demonstrate the technical feasibility of the product idea to external stakeholders in order to get their commitment. Therefore, commitments given to both investors and the early customer appear to explain the focused development of the gutter system throughout 2000 and 2003. Moreover, the outcome of the initial design experiments for the gutter system has revealed mixed outcomes. With the realization of the challenge of translating R&D into working applications, the firm has, in parallel, engaged in a more explorative period between 2000 and 2004. During this explorative period, they deployed the membrane technology in a wide range of applications in search for a business case based on the properties of their membrane technology. This phase was characterized by a number of affordable short-term design experiments conducted for different applications. On the one hand, these experiments had the goal to prove the membrane technology, and on the other hand, the goal was to generate alternative possibilities based on the membrane; thus getting market feedback from a diversity of segments and convincing early customers. Different to Solar Dew, with a limited amount of resources that became available, Vrachtfiets was able to achieve a working prototype in a relatively short period of time; however, the market signals were revealing that there might have been other market segments for the cargo bike concept. As a result, the firm redesigned its cargo bike concept for a diversity of markets throughout 2010 and 2011. Similarly, Sustainable Dance Club was not able to convince investors, or potential clients from its target segment until the end of 2008 and had realized that the dance floor was their flagship product due to the enormous attention it had been receiving from a variety of stakeholders and media. Thus, while the main priority of the firm was the clubbing market, the firm had probed alternative markets in parallel, and interacted with a number of potential partners and customers who could give their commitment in developing the floor. In the subsequent period, the firm had explored alternative markets for another application, namely the energy floor. In these explorative periods, the driver of design experiments appears to primarily explore alternative uses for product ideas and generate market feedback from a diversity of markets and get the commitment of early customers and to a less extent to test the technical feasibility of a specific product concept. The firms have been intensively interacting with a diversity of stakeholders prior to fully developed products or services.

Following the explorative periods, the innovation processes of the two case firms, Vrachtfiets and Solar Dew, display a focused pattern of PM development. The resources that became available during the process appear to influence the behavior of firms. In the case of Solar Dew, the firm acquired resources through an investor and focused on the development of a household water application for emerging markets: the black top collector. During this period, the product concept was evolving into the flex-bag concept due to technical issues, as well as the ambition to develop an affordable solution for the target market. The phase between 2006 and 2013 is characterized by the development of a series of working prototypes with moderate outcomes. Moreover, since the membrane failure in 2009, this phase is characterized by a number of proof of principle tests, mainly conducted in the laboratory. Although the team's perception of uncertainty had increased during this period, the availability of resources, and the sustainability motivation of the team appear to have influenced the firm to focus on a particular PM combination, as well as be a driver to test the technical feasibility of the product concepts to arrive at a working prototype. Similarly, since 2011, Vrachtfiets has been focusing on three versions of the cargo bike: 1) the pickup version for businesses in crowded areas such as inner cities and industrial sites, 2) the cargo version for the transport of goods and packages, and 3) the tourist version in combination with public transport. During this period, the team's main efforts went into the development of the tourist version due to an assignment given by the government through a subsidy.

In conclusion, the striking differences between the focused and explorative periods were the drivers for and type of design experiments, as well as stakeholder interactions. During the explorative periods, the primary driver for firms to conduct design experiments was to primarily to convince investors, partners and early customers and in this way to test the market feasibility of a variety of product concepts. Thus, the design experiments are mainly short-term, affordable, low-fidelity prototypes built in parallel to stakeholder interactions. On the contrary, the driver for design experiments during focused periods was to primarily test the technical feasibility of specific product concepts, due to the stronger commitments given to a product and/or market. During these focused periods, the availability of resources appears to influence the type and timing of experiments. If resources are available, the firms appear to conduct high-fidelity prototypes in shorter time frames.

7.2.3. Approaches to PM development

As elaborated in previous sections, the case firms' degree of focus and flexibility varies among the case firms and over time. On the basis of similarities and differences in the patterns of PM iterations, as well as the drivers for design experiments and stakeholder interactions, this study has identified two distinct approaches to PM development: 1) adaptive approach, characterized by a focus on a specific PM pair early on, experimenting with it for several years and adapting based on design experiments and stakeholder interactions; and 2) exaptive approach, characterized by a flexible attitude towards the PM pair and the use of design experiments instrumentally for generating alternatives and facilitating stakeholder interactions.

Adaptive approach

The three case firms, Solar Dew, Evening Breeze and Vrachtfiets, initially focused on specific PM combinations early on for several years and experimented with the same PM pair, hoping that the business idea would become viable. During these periods, entrepreneurs appear to engage with design experiments to primarily test the technical feasibility of a specific product idea. Furthermore, the driver for stakeholder interactions primarily appears to be generating customer feedback from the target market, and acquiring resources for the development of initial PM ideas.

In the case of Evening Breeze, the firm's initial assumptions appear to be correct as they were able to reduce technological and market uncertainties through the development of a working prototype, getting positive feedback from the potential customers within the target market, and eventually attracting investors within a time frame of two years. This appears to explain the firm's continuation with the same approach throughout the process. The firm has been iteratively developing the air-conditioning system based on the learning from design experiments and potential customers. Similarly, Solar Dew and Vrachtfiets have focused on specific PM pairs in the early years; however, the outcome of design experiments and stakeholder interactions revealed that the initial assumptions were incorrect, or there were other ways to approach the market. Consequently, following the initial adaptive period, these two firms have been adapting an exaptive approach to PM development.

Similarly, soon after the idea of using a new polymer for water desalination emerged in 1998, Solar Dew initially focused on the development of the irrigation mat concept for agro-businesses. The team continued to develop this idea for a year, and subsequently shifted to a different product concept in 2000, i.e. the gutter system, due to the technical problems encountered during the initial design experiments. At the end of 2000, the firm's target market was shifting to formation water due to the necessity to convince investors to continue with the development. During the period of 1998 and 2003, the team conducted a series of design experiments (various lab and field trials, and a large-scale demonstration project resulting in a potential customer) in order to develop a proof of concept. Meanwhile, the main stakeholder interactions were investors and potential customers from the target market, with the driver for acquiring resources and generating market feedback on specific PM pairs. The team's perceived technological uncertainty increased due to the mixed outcome of design experiments between 2000 and 2002. Subsequently, in parallel to the focused development of the gutter system, the firm engaged with exaptive experimentation throughout 2000-2004 and conducted simultaneous PM iterations for a period of four years.

Similarly, in the early years, Vrachtfiets focused on the development of the cargo bike concept for students in Delft, and wrote a business plan with the support of an incubator at Delft University of Technology. During this time, Vrachtfiets was unable to engage in design experiments due to resource constraints; however, between 2007 and 2009, the firm conceptually developed a product-service system idea. In this concept, the cargo bike was offered as a service to the students in Delft, and the revenues were hoped to be generated through the mobile advertisements given by various companies on the bike. During this period, the firm's main interactions were with funding organizations, in order to acquire the resources needed to develop an initial prototype. As soon as the firm was established in 2009, and a working prototype was built, the founders realized that there could be alternative markets based on the feedback from different stakeholders.

In summary, an adaptive approach is characterized by a commitment to a specific PM combination for a longer period of time, iterative development based on learning from design experiments, and feedback from potential customers from a specific market segment.

In this case, entrepreneurs use design experiments to test the technical feasibility and market viability of a specific PM pair. In that sense, an adaptive approach primarily represents a causal logic, since the driver for conducting design experiments as well as engaging with stakeholder interactions, is to test the feasibility and viability of a predefined PM definition. While positive outcomes provide reassurance for the initial PM pair, mixed and negative outcomes are likely to result in subsequent design experiments and stakeholder interactions, as well as shifts in the PM pair, eventually shifting to an exaptive approach when the firms are not able to decrease uncertainties.

Exaptive approach

In contrast to the other three case firms, Sustainable Dance Club appears to have a different approach throughout the innovation process. Although the firm had a strong focus on clubs in the early years, it was flexible with the definition of product and service concepts. As a result, during the period between 2005 and 2009, the firm engaged in a variety of product iterations and conducted affordable design experiments without necessarily committing to a specific product idea. These design experiments were conducted with the goal to attract potential clients and partners, who would be willing to co-develop the 'sustainable dance club' idea further. Soon after the realization that the dance floor was attracting the attention of diverse stakeholders, the firm begun probing alternative markets for the dance floor idea in order to develop it further. Sustainable Dance Club failed to convince external actors for co-development during this period, but nevertheless in 2008, the firm decided to focus on the development of the dance floor idea; due the enormous attention the floor was receiving in the media, as well as among potential customers who were showing interest in buying the product once it was ready. Similarly, when the focus was given to the development of the energy floor idea in 2010, the main driver of initial stakeholder interactions was to attract the attention of potential customers who would be willing to co-develop the idea. Hence, the types of initial design experiments were low-fidelity prototypes that were conducted with the goal of exploring alternative uses for the floor and stimulate stakeholder interactions.

The periods that Solar Dew (2000-2004) and Vrachtfiets (2010-2012) engaged in an exaptive approach, show similar patterns of PM iterations and drivers for design experiments. In the case of Solar Dew, a high technological uncertainty stemming from the challenge of translating a new technology into applications, appears to have necessitated a more flexible approach to the product and market definition than products that embody existing technologies. Solar Dew had deployed the unique properties of its membrane technology into a wide range of applications for a diverse range of markets. Parallel to affordable design experiments, the firm engaged with potential customers in order to gain their commitment. Similarly, Vrachtfiets engaged with an exaptive approach, with the realization of alternative markets based upon the feedback from various stakeholders. During this period, the firm engaged with simultaneous PM iterations and design experiments, with the aim of getting the commitment of potential customers, and testing which markets would take off.

In summary, an exaptive approach is characterized by short-term simultaneous experiments with various product concepts and/or target segments, without necessarily committing to a specific PM pair. In this case, design experiments are instrumental in generating alternative solutions, and facilitating the self-selection process of stakeholders and potential customers from various market segments, in order to co-develop products ideas further. Thereby, an exaptive approach primarily follows an effectual logic, as firms are likely to be more open to shifting to alternative product ideas and/or target segments based on the feedback from design experiments and stakeholder interactions.

7.3. EXPLAINING THE PRODUCT INNOVATION PROCESS

The case firms display similar and different patterns regarding PM iterations. In order to explain these similarities and differences, a number of factors were proposed in Chapter 5. The influences of these explanatory factors have been analyzed in this chapter. In this section, the previous analysis will be discussed along the propositions that were proposed in Chapter 5. The propositions address how and why firms have engaged in various PM iterations.

7.3.1. Testing the propositions

Proposition 1: Shifts in PM combinations

The first proposition addresses the implications of the type of opportunity for the innovation process. The conceptual model suggests that the shifts in PM combinations are driven mainly by two types of actions: design experiments and stakeholder interactions. It was suggested that the type of innovation and the associated market and technological uncertainty have implications for the product innovation process. In order to explain what drives PM goals in different types of innovation, the following proposition was proposed:

P1. The definition of the product-market pair is primarily driven by design experiments in the case of high technological uncertainty.

This proposition has been confirmed from the case study data. For the cases that involved both high and moderate levels of technological uncertainty, the PM shifts were primarily triggered by the negative outcome of design experiments. Based on the newness of technologies for firms and their respective industries, as well as the level of technological uncertainty, the firms were ordered in Chapter 5 from high to low: Solar Dew, Sustainable Dance Club, Evening Breeze and Vrachtfiets. Particularly in the case of Solar Dew, the majority of PM shifts have resulted from the mixed and negative outcomes of design experiments. This stimulated the firm to search for alternative applications for both the same target market and alternative markets, based on various applications throughout the innovation process. Similarly, one of the drivers for Sustainable Dance Club to shift from clubs to alternative markets was the outcome of a design experiment, which revealed that covering the energy demand of clubs through the dance floor, even partly, was technically not feasible. This triggered the firm to focus more on the promotional value of the dance floor, i.e. 'creating awareness among young people' instead of 'powering clubs'. Subsequently, the business model shifted from a sales model to a rental one, with a greater focus on event companies, a shift in the market segment, and the development of complementary products such as energy displays.

In addition, Evening Breeze and Vrachtfiets were relatively fast in reducing technological uncertainties by developing working prototypes and early versions of their product, and subsequently engaging in a number of stakeholder interactions. In both cases, the PM iterations were primarily driven by stakeholder interactions. Although in the case of Evening Breeze, the outcome of the design experiments was a driver for the development of a stand-alone version, the shift from the hospitality market to the consumer market appears to be due to proximity reasons and positive feedback, lowering the team's perceived market uncertainty. Subsequently, the firm shifted from the consumer market to the hospitality market due to the mixed outcome of interactions with potential clients, which revealed that the bed manufacturing industry had declined due to the financial crises in 2008. Similarly, Vrachtfiets engaged with a number of potential clients in an effort to reduce market uncertainties and arrive a stable business model. The outcome of these interactions resulted in the redesign of the cargo bike, based on the development of new modules as required by stakeholders.

Proposition 2: Patterns of PM iterations

This proposition addresses the implications of the level of expertise and resources on the innovation process. Taking the link between entrepreneurial expertise and effectuation as a departing point, Chapter 4 proposed that expert entrepreneurs are more likely to be flexible with the definition of the PM pair, in comparison to novices. Consequently, the following proposition was proposed:

P2. In comparison to novices, expert entrepreneurs are likely to engage with a higher number of short-term product-market combinations during the product innovation process. The novice entrepreneurs' approach is more likely to be moderated by the availability of resources.

This proposition has been largely confirmed: the periods that were managed by expert entrepreneurs yielded a higher number of short-term product market combinations, in comparison to the periods that were managed by novices. Apparently, expert entrepreneurs explore a wider range of applications and markets based on available means in order to increase the chance of success. In the case of Solar Dew, the firm developed a number of product concepts for a diverse number of markets based on the unique properties of its membrane technology between 2000 and 2005. Similarly, between 2005 and 2009, Sustainable Dance Club engaged in a number of product concepts based on the founders' motivation to transform the clubbing market, as well as a number of potential markets between 2006-2010 and 2010-2013 based on the knowledge and capabilities gained through the development of dance floor idea. Furthermore, Vrachtfiets was highly iterative during the period of 2010-2012, although the firm was managed by novice entrepreneurs. In this period, the firm relied upon external resources for further development, and developed early versions only based on demand. As a result, the scarcity of resources triggered a more iterative pattern of PM definitions.

Although the analysis of these highly iterative periods show how expert entrepreneurs are likely to be more flexible with the definition of PM pair, the cases such as Sustainable Dance Club (2005-2009; focus on clubs) and Solar Dew (2006-2008; focus on the BoP market) show how experts are not entirely flexible with the definition of both products and markets, arguably given their expertise. This shows how expertise does not automatically result in flexibility with market development. Sustainability motivation of the entrepreneurs also proves to be an important factor, particularly when the focus is on a specific market segment, to the extent that it is dominant over expertise. Consequently, this suggests that firms are seldom flexible with both product ideas and market segments. The firms appear to anchor on a product idea or a specific segment, even though they are managed by experts. These finding confirm the expectation that both effectual and causal logics might be used simultaneously (Reymen et al., 2015), which result in an adaptive and exaptive approach, respectively. Furthermore, it also confirms the argument that an opportunity may entail both risky and uncertain aspects, thus might require entrepreneurs to engage in opportunity discovery and creation processes simultaneously (Alvarez et al., 2013). Therefore, the second proposition is reformulated as follows:

RP2. Expert entrepreneurs are likely to be more flexible with the definition of product-market combinations to the extent that their expertise is dominant over their sustainability motivation. The novice entrepreneurs' approach is more likely to be moderated by the availability of resources.

Proposition 3: Consequence of initial actions and shift in patterns of PM iterations
This proposition addresses the rationale behind the shifts in pattern of PM iterations and approaches to PM development. It suggests that the outcome of design experiments and stakeholder interactions influences the behavior of firms. The initial assumptions are likely to be incorrect, optimistic, and idealistic and thus, modified as the ventures engage in design experiments and stakeholder interactions. Learning from design experiments and feedback from stakeholder interactions was expected to cause a change in the entrepreneurs' perception of uncertainty, and consequently, in the behavior of firms. The tentative proposition that was proposed in Chapter 5 was:

P3. A high level of perceived uncertainty that stems from the negative and mixed outcome of design experiments and stakeholder interactions, is likely to result in a higher number of short-term product-market iterations, and vice versa.

This proposition is largely confirmed in this research as the case study demonstrates how periods of focused development alternate with periods of iterative development, based on a change in entrepreneurs' perception of uncertainty. Both Solar Dew and Vrachtfiets initially adapted a more focused approach and started experimenting with the same PM pair, subsequently transitioning into a more iterative phase of development, based on the outcome of design and stakeholder cycles. In contrast, Sustainable Dance Club has initially been more flexible with the definition of the product; however, the firm later transitioned to a more focused period of product development, based on the outcome of design and stakeholder interactions. On the one hand, the challenge of translating human power into electricity was shifting the focus of the firm from decreasing the environmental impact of clubs to creating awareness on the concepts of sustainability. On the other hand, the positive feedback from various stakeholders was stimulating a search for alternative markets. Similarly, Solar Dew and Vrachtfiets adapted a more focused approach following the iterative phase. In the case of Solar Dew, lessons from previous design experiments, a shift from large-scale applications to small-scale applications, as well as the resources that became available through an investor, appear to have decreased the entrepreneurs' perceived uncertainty. Similarly, the Vrachtfiets case suggests that lessons from previous design experiments and the resources that became available through a subsidy appear to have decreased the entrepreneurs' perceived uncertainty, which arguably stimulated a more focused approach between 2011 and 2013.

Proposition 4: Influence of sustainability motivation

This proposition addresses the influence of entrepreneurs' sustainability motivation on the innovation process. In Chapter 5, it was suggested that a high level of environmental ambition is likely to escalate the commitment of decision makers and thus lock the project team into a course of action. Therefore, the following proposition was proposed:

P4. Sustainability motivation is likely to decrease the number of product-market iterations while increasing their duration.

This proposition implies that sustainability motivation is likely to increase the commitment of entrepreneurs to a specific PM combination, thus increase its duration while making the shifts to alternative PM combinations a painful and difficult decision. Although the cases of Solar Dew (particularly the periods 1998-2003 and 2006-2013) and Sustainable Dance Club (the period 2005-2009) show how sustainability motivation appears to lower the performance threshold and influence go/no-go decisions, the iterative periods of Vrachtfiets (2010-2012), Solar Dew (2000-2004) and Sustainable Dance Club (2006-2009 and 2010-2013), as well as Evening Breeze (the shift from hospitality to consumer market) show how firms can easily shift to alternative markets. Apparently, how entrepreneurs identify an opportunity in relation to sustainability influences the ease of justifying sustainability claims for alternative markets. In other words, a high degree of change that entrepreneurs aim to bring into a specific market appears to increase the duration of PM combinations. On the other hand, product ideas that can potentially replace existing products in a diverse number of markets appear to ease the justification of similar sustainability claims for alternative markets, at least in entrepreneurs' mind. As a result, this proposition partly holds and is reformulated as follows:

RP4: Sustainability motivation is likely to increase the duration of product-market iterations and decrease the number of product-market iterations, unless justifying sustainability benefits for other market segments, at least in entrepreneurs' mind, is relatively easy.

7.3.2. New proposition

Proposition 5: Role of design experiments

Based on the analysis and comparison of case firms, this study shows how the degree of focus and flexibility varies over time and among the case firms. Furthermore, a closer look at the focused and explorative periods has revealed different drivers for design experiments and stakeholder interactions. On the basis of these differences, this study has identified two distinct approaches to PM development: 1) adaptive approach, characterized by a focus on a specific PM pair early on, experimenting with it for several years and adapting based on design experiments and stakeholder interactions; and 2) exaptive approach, characterized by a flexible attitude towards the PM pair with a strong focus on stakeholder interactions.

An adaptive approach appears to reflect a causal logic, since the driver for conducting design experiments and engaging with stakeholder interactions is to test the feasibility and viability of a predefined PM definition. On the contrary, an exaptive approach reflects an effectual logic, since the driver for design experiments appears to generate new possibilities and stimulate the self-selection process of stakeholders, without committing to a particular product definition. In that sense, design experiments are rather instrumental in stimulating stakeholder interactions and getting their commitment in co-developing product ideas further. Based on these observations, the following proposition is formulated for further testing in future research:

P5. Design experiments are likely to be instrumental when firms engage in an exaptive approach.

7.4. CONCLUSIONS

This chapter had the goal to answer the following research questions:

- What patterns of product innovation processes can be identified? (RQ 2b)
- What explains the similarities and differences in patterns of product innovation processes? (RQ 2c)
- How does sustainability motivation influence the decision-making process, in particular the definition of product-market combinations? (RQ 3b)
- How does sustainability motivation evolve over time? (RQ 3c)

Four cases have been selected and analyzed based upon a variation of the dependent variables of the descriptive model of the product innovation process (section 5.2). In the previous sections, the similarities and differences among case firms' product innovation processes have been discussed including the patterns of PM iterations, design experiments and stakeholder interactions. In addition, taking the causation-effectuation dichotomy as a departing point, the explanatory constructs identified in the literature have been addressed, in order to better understand these similarities and differences. It can be concluded that the conceptual model is largely validated based upon this case study data. The model suggests that the interplay of these factors help explain how and why firms engage in both similar and different patterns of PM iterations over time.

This study finds evidence for the argument that the different patterns may reflect the differences in the level of expertise of entrepreneurs and resources. Experts appear to use predominantly effectual logic in comparison to novices; as such the periods that have been managed by expert entrepreneurs show a more iterative pattern of PM development compared to the periods managed by novices. However, this case study also demonstrates how firms are seldom iterative with both product and market definition. This supports the argument that causal and effectual logics might be used simultaneously (Reymen et al., 2015). The sustainability motivation of entrepreneurs appears to prove an important factor, to the extent that motivation dominates over expertise. In addition, sustainability motivation appears to influence the justification of sustainability claims for other market segments, and consequently, the PM iterations the firms engage in over time.

Finally, this study shows how the periods of focused and iterative patterns of PM definitions alternate over time. The lessons from design experiments and the feedback from stakeholder interactions appear to cause a change in entrepreneurs' level of perceived uncertainty and sustainability motivation, consequently influencing the product innovation process in new ventures. In particular, a high level of perceived uncertainty appears to stimulate an exaptive approach to PM development, as it causes entrepreneurs to downsize the social or environmental goals or mute them, until the uncertainty is reduced through the outcome of design experiments and stakeholder interactions.

Chapter 8

Conclusions and Recommendations

New ventures are confronted with a variety of uncertainties, i.e. uncertainties pertaining to the innovation itself, uncertainties linked to the sustainability benefits of the innovation, and resource uncertainties linked to being a small and new firm. Considering the challenge of defining a product-market (PM) combination in the face of these uncertainties, this thesis has sought to describe and explain the product innovation process in sustainability-oriented new ventures, addressing the following main research question:

How does the product innovation process evolve in sustainability-oriented new ventures?

In order to answer these questions, the first part of the thesis presented a theoretical inquiry. Firstly, the literature on innovation was reviewed, focusing on the implications of novelty of an innovation on the innovation process. It was concluded that new ventures are often unable to identify a PM combination at the outset of the innovation process, and are expected to progressively define their business idea. roduct development in new ventures unfolds in an iterative manner, in which firms learn about the opportunities and limitations of the technical and market feasibility of their idea through a number of design experiments. In some cases, the outcome of design experiments result in optimizations or redesigns; however, in some cases, they result in radical shifts, i.e. a different application or a different market segment. Furthermore, in order to explain the differences in the product innovation process in new ventures, this study has chosen to deploy an emerging decision-making theory in the area of entrepreneurship. Effectuation highlights the role of stakeholder commitments in driving product-market related decisions, and offers a number of factors that appear to explain the differences in the approach of firms to PM development. Furthermore, sustainable entrepreneurship literature has been reviewed, with a focus on the implications of sustainability motivation on the decision making process. The literature review enabled the development of a descriptive and explanatory conceptual model as well as a set of propositions. Subsequently, a longitudinal case study research was conducted, in which four sustainability-oriented new ventures were described and analyzed.

This chapter presents the main research findings from the case study by answering the research questions (section 8.1). It then discusses the implications for theory (section 8.2), followed by explanations on the limitations of this study (section 8.3). Finally, this chapter presents the implications and recommendations for practice (8.4), design education (8.5), and policy (8.6).

8.1. MAIN RESEARCH FINDINGS: PRODUCT INNOVATION IN NEW VENTURES

This study aims at gaining a more profound understanding of the product innovation process in sustainability-oriented new ventures. This section summarizes the observations from the case study; in particular, how new ventures manage the process of product innovation, and the implications of sustainability ambition on this process. The main research findings are discussed along the research questions.

8.1.1. Describing the innovation process in new ventures

The first research question raised in Chapter 1 was:

1. How can the product innovation in new ventures be described?

With this question, the aim was to gain a better understanding of how product innovation evolves in new ventures; in particular which approaches new ventures use in managing product innovation, and what actions drive the evolution of PM definitions. Answering this question makes it possible to understand how sustainability motivation influences the product innovation process in new ventures. For this purpose, a theoretical inquiry was conducted. Chapter 2 and 3 reviewed the literature on innovation management and entrepreneurship, respectively. Based upon a synthesis of theoretical perspectives in the literature, a model to describe product innovation process in new ventures was proposed in Chapter 5. This model suggests that the product innovation process in new ventures can be described by capturing the way new ventures iterate with PM combinations over time, and the way they engage in design experiments and stakeholder interactions. The underlying assumptions of the model are as follows:

- New ventures define an initial PM combination based on a set of available means.
- The product innovation process in new ventures follows an iterative fashion with less stable PM definitions; thus defining a promising PM combination at the outset of the process is difficult.
- The definitions of the PM pair are driven by two distinct actions: design experiments and stakeholder interactions.

These theoretical insights have been compared with the empirical results in order to validate the descriptive model. The assumptions underlying the descriptive model are largely confirmed in four empirical cases. The findings based upon the descriptive model are discussed in the following paragraphs.

Definition of initial PM

In line with the first assumption mentioned above, all case firms defined an initial PM combination based on a set of available means rather causal methods such as market research and calculation of potential returns. In particular, the ease of access to potential customers and partners through prior network, prior knowledge of the founders, and personal preferences in relation to sustainability appear to be the means that drive the definition of the initial PM pair. More specifically, in the case of Solar Dew, the technology at hand and its unique properties, as well as the firm's established customer base among agro-businesses lead to the irrigation mat concept. Similarly, the founders of Evening Breeze began with their experience in eco-room projects and their network among eco-resorts. Using this experience, together with the ambition to decrease the environmental impact of resorts, they developed the airco bed idea for eco-resorts. The founders of Vrachtfiets also began with a problem that they often faced as students and developed the cargo bike concept, which could be applicable to a variety of markets. Due to their network among students and the ease of access to sponsors in Delft, they initially chose students as the initial target segment. Different to this, the founders of Sustainable Dance Club did not have a prior network or experience with clubs. In this case, the personal preference of the founders, particularly in relation to sustainability and dancing, were the main means that entrepreneurs were deploying to define the initial PM pair.

Difficulty of defining a PM combination at the outset
This study shows that, in line with the second assumption above, identifying a PM combination at the outset of product innovation process is a challenging task for new ventures. New ventures face distinct challenges due to their organizational characteristics and uncertainties in relation to sustainability. As a result, all firms have engaged in product concepts and/or target segments that they had not initially imagined at the outset of the innovation process, thus they have progressively defined the definition of the PM combination. The definition of the PM pair evolved radically in the case of Solar Dew, and more smoothly in the cases of Sustainable Dance Club, Evening Breeze and Vrachtfiets.

Actions that drive the definition of PM combinations
As proposed in the descriptive model, analysis of this case study confirmed the third assumption. The product innovation process is characterized by two distinct actions that drive the definition of PM pair: design experiments and stakeholder interactions. These actions influenced the PM goals to varying degrees among the case firms. Although the outcome of a design experiment or stakeholder interaction did not result in a shift in the PM combinations in all cases, all shifts were driven by these two types of actions. In some cases, the trigger for a PM iteration was the combined effect of these two actions, and in other cases it was the combined effect of both the actions and the factors that had been suggested in the conceptual model.

8.1.2. Explaining the innovation process

The second research question raised in Chapter 1 was:

2. What explains the differences and similarities among new ventures' product innovation processes, in particular the evolution of product-market definitions?

This research question aimed at identifying the similarities and differences among new ventures' product innovation process on the basis of the variables of the descriptive model. Although the case firms appear to be similar in terms of how they initially and progressively define their PM pair, differences were observed regarding: (i) the type of action that drives the PM definitions, (ii) the patterns of PM iterations, and (iii) consequently the drivers, type, timing and number of design experiments and stakeholder interactions. On the basis of the causation-effectuation dichotomy, Chapter 5 proposed a number of interrelated factors that might explain these differences: entrepreneurial expertise, resource position, perceived uncertainty, type of innovation, and sustainability motivation of the entrepreneurs. This study concludes that the interplay of above factors helps to explain the type of approach that firms adapt, and how they decide to what do next and shift to alternative product concepts and/or market segments. In the following paragraphs, the similarities and differences, as well as the factors that might explain these similarities and differences are discussed.

PM definitions

Initial PM

Despite the similar way that the case firms define an initial PM pair, i.e. by using a set of available means, they differ in their early focus. The firms appear to anchor on a product idea, or a specific target market early in the process and focus on either the product or market development. Two of the case firms (Evening Breeze and Solar Dew) had initially focused on a specific product idea and a target market; one case firm (Vrachtfiets) chose to focus on a specific product, and experimented with various markets; and one case firm (Sustainable Dance Club) chose to focus on a specific target market and experimented with various product ideas. The conceptual model proposes a number of factors in explaining the differences in innovation processes: 1) the type of innovation, 2) entrepreneurial expertise, 3) resource position, 4) sustainability motivation and 5) perceived technological and market uncertainty. Which of these factors best explains the differences in approaches?

The analysis of the case study suggested that the anchoring process appears to be better explained by the sustainability motivation of the entrepreneurs, and their perception of uncertainty, which is strongly correlated with the type of means that lead to the initial definition of the PM. The sustainability motivation appears to influence how the firm addresses an issue related to sustainability. On the one hand, if entrepreneurs' motivation is to change a specific market towards more sustainable practices, firms anchor on a market and the product idea(s) follow this initial market definition. On the other hand, if the motivation is to develop a product applicable in multiple markets, the firms anchor to a specific product idea and the market idea(s) follow this initial product definition.

The categories of means that entrepreneurs use in defining an initial PM combination are equally important in explaining this anchoring process. Sarasvathy (2008) proposes three categories of means, which entrepreneurs use: who I am, what I know, and whom I know. What I know and whom I know can be further subdivided into: product related knowledge, skills and network, and market related knowledge and network. The knowledge, skills or network in relation to product development are likely to reduce the entrepreneurs' perception of technical uncertainty, whereas knowledge or network in relation to market development are likely to reduce perception of market uncertainty. This is not to say that entrepreneurs perceive no or a low level of uncertainty, but previous knowledge, experience and network appear to stimulate entrepreneurs to focus on one of the components of the PM pair. For instance, in the case studied in this thesis, entrepreneurs' design skills and the knowledge of a specific technology were seen to stimulate their focus on a specific product idea. Similarly seen in the case firms, previous knowledge and experience in a specific market, as well as access to customers in a market have stimulated entrepreneurs to focus on a specific market segment.

Interestingly, this study did not find a strong correlation between expertise and use of network in the definition of the initial PM pair. Sarasvathy (2008) suggested that extreme effectuators, i.e. expert entrepreneurs, begin with partners/customers in their existing network as the preferred method of developing a segment definition. Only one case firm was initially managed by an expert entrepreneur in this study. In this case, the founder's personal preferences in relation to dancing and sustainability were the main sources for initial market selection. On the other hand, the three case firms with novice entrepreneurs had used their network more extensively in the market selection. These findings suggest that sustainability motivation, in relation to a high degree of change entrepreneurs aim to bring to a particular market, is likely to overrule other categories of means as sources for the initial definition of PM pair.

Thus, the sustainability motivation combined with the differences in firms' use of their means can explain the differences in commitment to a specific product idea and/or target market among entrepreneurs.

Evolution of the PM definition

The descriptive model that was presented in Chapter 5 suggests that firms engage in a series of design experiments and stakeholder interactions, and the outcome of these actions is expected to influence the product-market related goals. The positive or negative outcome of these two types of actions provides feedback on the technical and market feasibility of initial PM ideas. However, under what circumstances does a design experiment or stakeholder interaction drive the PM goals?

The positive feedback from design experiments was expected to have no influence on PM goals. As Thomke (1998) suggests, if an experiment is successful, the trial and error process stops. Similarly, it was expected that positive feedback from the target market (particularly without commitments) would have no influence on goals. In these situations, the amount of learning is limited since firms get a confirmation on their initial assumptions, i.e. whether a product idea is technically feasible, and whether a demand exists for a product. The case study data confirms this expectation. The positive outcome of design experiments and stakeholder interactions did not influence the product-market related goals; instead it resulted in an optimization of the product ideas.

On the other hand, the mixed and negative outcomes of these two actions appear to have influenced the PM goals to varying degrees. Regarding the type of action that drives the PM definition, this study observed that the type of innovation and associated technological uncertainty have implications on the evolution of PM definition. The case study has shown that the shifts in PM definitions are primarily driven by design experiments and stakeholder interactions. In particular, in the case of high and moderate levels of technological uncertainty, design experiments is likely to influence the definition of PM pair at higher degree in comparison to cases with low technological uncertainty. These findings are in line with the suggestion that trial and error type of experiments, often conducted in controlled environments, are more suitable for resolving product or technology related uncertainties, whereas effectuation is more relevant in resolving market related uncertainties through stakeholder commitments (Silberzahn, 2011). In particular, the Solar Dew case suggests that the challenge of translating a new technology into a working prototype stimulates a search for alternative product concepts; aimed at both the same and alternative markets. Similarly, in the case of Sustainable Dance Club, the challenge of translating the energy from dancing into electricity that can partly power the clubs, was an important stimulus to focus more on the social aspects and creating awareness. This resulted in the development of complementary products such as energy displays, and eventually the decision to discontinue with the clubbing market. Apparently, translating a new technology into working applications in a short time frame is challenging. Design experiments provide firms with insight into the limitations and opportunities in relation to a product idea or technology. In particular, decisions concerning the development of new products appear to be driven by the negative outcome of design experiments and the ambition to serve a specific market, which is partly linked to the sustainability motivation of entrepreneurs. Furthermore, besides the direct effect of design experiments, in some cases, they had indirect effects that stimulated the self-selection process of stakeholders, which in some cases resulted in actual commitments, leading to a PM iteration. It can be argued that in these situations, the design experiments were instrumental; the firms used prototypes or intermediate outcomes to explore alternative ideas and gain the commitment of external stakeholders.

Moreover, when firms are able to arrive at a proof of concept faster, i.e. when the technological uncertainty is relatively low, the shifts in PM iterations are primarily driven by stakeholder interactions. The analysis of the case study suggested that a series of negative feedback from the target market and/or positive feedback from other markets stimulates a search for alternative markets, or a shift into other segments. In particular, decisions concerning shifts to new target segments or markets appear to be driven by the necessity to convince external stakeholders such as investors or early customers (and as a result generate initial revenues), which is moderated by the ease of justification of similar sustainability claims in different markets.

Patterns of PM iterations

This study has observed different patterns of PM iterations based on the firms' degree of focus and flexibility over time. The PM iterations appear to show divergence and convergence over time, i.e. in some cases focused periods follow explorative periods, and vice versa. Consequently, the duration and number of PM iterations differed between the case firms. Some firms engaged in a higher number of product iterations and/or market segments than others, and at different times. The duration of the product iterations and market segments differed between cases, and at different phases of the processes. What explains the differences in patterns of PM iterations?

Apparently, the expertise of the entrepreneurs has an influence on the different patterns of PM iterations. This study has observed that the periods managed by expert entrepreneurs have resulted in a higher number of short-term product and/or market iterations in comparison to periods that have been managed by novices. Expert entrepreneurs appear to imagine a wide range of applications for alternative markets in order to increase the chance of success. Furthermore, the case of Vrachtfiets has shown how novice entrepreneurs might engage with a more iterative fashion in the development of a PM pair. This supports the proposition that resource constraint was an important factor that influenced the patterns of PM iterations.

Furthermore, although the expertise and iterative periods correlates to some extent, cases such as Sustainable Dance Club (2005-2009) and Solar Dew (2000-2003 and 2006-2008) show how experts are not entirely flexible with the definition of both products and markets, arguably given their expertise. This shows how expertise does not automatically result in flexibility in market development. Sustainability motivation of the entrepreneurs also proves to be an important factor, particularly with a focus on a specific market segment, and to the extent that it is dominant over expertise. Consequently, this suggests that firms are seldom flexible with both product ideas and market segments. The firms appear to anchor on a product idea or a specific segment even though they are managed by experts. This finding confirms with the expectation that effectual and causal logic might be used simultaneously (Reymen et al., 2015). Furthermore, it also confirms the argument that an opportunity may entail both risky and uncertain aspects, requiring entrepreneurs to engage in the opportunity discovery and creation processes simultaneously (Alvarez et al., 2013).

In summary, the combined effect of expertise and sustainability motivation of the founders and firms' resource position appears to explain the differences in PM iterations among the case firms.

Shift in patterns of PM iterations

The case study demonstrates how periods of focused development alternate with periods of explorative development differently for each case firm. Three of the case firms focused on specific PM combinations early in the process for several years, and experimented with the same PM pair, in hope that the business idea would become viable. If their initial assumptions are confirmed, and the firms are able to reduce uncertainty through design experiments and stakeholder interactions, this focused pattern of PM development continues. However, in the cases where the initial assumptions appear to be incorrect, the firms appear to engage in a more explorative pattern of PM development following the focused period. Furthermore, the case of Sustainable Dance Club suggests that firms can also initially engage in an explorative pattern of PM development. What explains the shift in patterns of PM iterations?

The analysis of shifts from a divergent to a convergent phase, and vice versa, revealed that the shifts occurred based upon a change in the degree of the entrepreneurs' perception of uncertainty. The entrepreneurs' perception of uncertainty appears to change based on the outcome of design experiments and stakeholder interactions, as well as a change in the resource position of the firm. This finding is supported by the suggestion that the use of effectual logic is driven by a high level of perceived uncertainty, and a low level of resource position; and the use of causal logic is increased by a low level of perceived uncertainty, and an increase in a ventures resource position (Reymen et al., 2015; Sarasvathy, 2008). Explorative periods in the case study appear to be triggered by an increase in the level of entrepreneurs' perceived uncertainty. More specifically, in cases where the outcome of a series of design and stakeholder cycles reveal negative or mixed outcomes, the entrepreneurs' perception of uncertainty appears to increase, which stimulates a more explorative pattern of PM iterations. This finding confirms the concept of 'search breadth' and 'scoping decisions', as suggested by Reymen et al. (2015). An increase in the perception of uncertainty appears to increase the use of effectual logic, thus resulting in a widening in the venture scope, and a more flexible pattern of PM development. On the other hand, in cases where the outcome of design and stakeholder cycles reveal positive outcomes, and when resources become available along the process, the entrepreneurs' perception of uncertainty appears to decrease, stimulating a more focused pattern of PM iterations.

Patterns of design experiments and stakeholder interactions

Given the uncertainties in the early phases of the innovation process, the question is how do firms decide what to next; in particular, whether to engage with design experiments of stakeholder interactions, and why? Behavioral implications of effectuation suggest that expert entrepreneurs engage with stakeholder interactions prior to having a fully developed product, and conduct inexpensive design experiments before fully committing to specific product idea, i.e. allowing the product concepts to emerge based on both stakeholder interactions and design experiments. In contrast, novice entrepreneurs are expected to postpone stakeholder interactions and give priority to product development according to a vision and plan. In other words, novice entrepreneurs are likely to conduct more expensive, high fidelity design experiments, whose timing is likely to be later in the process. As a result, a key difference between novices and experts is the timing and drivers for design experiments and stakeholder interactions: earlier stakeholder interactions and (low cost and low fidelity) design experiments versus later stakeholder interactions and (high cost and high fidelity) design experiments.

The case study largely supports this expectation. Expert entrepreneurs have been intensively engaging in stakeholder interactions and design experiments immediately, in order to flexibly define the product concepts and target markets before fully committing to a specific PM pair. In these cases, design experiments, to a certain extent, were instrumental in getting feedback from stakeholders. On the other hand, with novice entrepreneurs, design experiments were conducted in order to test the technical feasibility of specific product concepts and adopt them based on the outcome of experiments. Moreover, the drivers for stakeholder interactions in these periods were either to acquire resources for, or getting feedback on a predefined PM pair, and not necessarily being flexible with the PM pair.

Type of approaches to PM development

The comparison of innovation processes revealed differences in the timing and drivers for design experiments and stakeholder interactions, as well as the duration of PM iterations. Based on these observations, two distinct types of approach have been identified: (1) adaptive approach, and (2) exaptive approach.

An adaptive approach is characterized by a commitment to a specific PM combination for a longer period of time, and by iterative development based on learning from design experiments, as well as feedback from potential customers from a specific market segment. In this case, entrepreneurs use design experiments to test the technical feasibility and market viability of a specific PM pair. In this regard, an adaptive approach primarily represents a causal logic, since the driver for conducting design experiments and engaging with stakeholder interactions is to test the feasibility and viability of a predefined PM pair. While positive outcomes provide reassurance for the initial PM pair, mixed and negative outcomes are likely to result in subsequent design experiments and stakeholder interactions, and in some cases a shift of the PM pair.

On the other hand, an exaptive approach is characterized by short-term simultaneous experiments with various product concepts and/or target segments, without necessarily committing to a specific PM pair. In this case, the design experiments are instrumental in facilitating the self-selection process of stakeholders and potential customers from various market segments in order to co-develop products ideas further. Thereby, an exaptive approach primarily follows an effectual logic, as firms are likely to be more open to shifting to alternative product ideas and/or target segments based on the feedback from design experiments and stakeholder interactions. Furthermore, the analysis of exaptive periods shows how expert entrepreneurs are not entirely flexible with PM definitions. The motivation to change a particular market towards sustainable practices appear to stimulate firms to anchor on a specific market even though they engage in an exaptive approach.

8.1.3. The role of sustainability motivation

The third research question raised in Chapter 1 was:

3. How does the sustainability motivation of entrepreneurs influence the product innovation process?

With this question, the aim was to explore how different motivations of entrepreneurs influence the product innovation process, and how these motivations evolve over time. Although the influence of sustainability motivation is touched upon in the previous paragraphs, in this paragraph an overview is presented. The motivation of entrepreneurs in relation to sustainability appears to influence the innovation process in various ways, particularly regarding the definition of initial PM pair and the pattern of PM iterations.

First of all, the case study suggests that sustainability motivation influences the way the firm addresses an issue related to sustainability, and consequently influences the degree of focus on and flexibility with a specific product or market definition. While the motivation to change a specific market towards more sustainable practices causes firms to anchor on a target market, the motivation to develop a product that can replace existing products in a diversity of market appears to cause firms to anchor on a product idea. This finding has implications in how the patterns of PM iterations follow.

In cases, where an opportunity has emerged from the motivation to transform a market, entrepreneurs appear to be more reluctant to shift to alternative markets, even though the market signals indicate to do so. In other words, the motivation to transform a market appears to increase the commitment of entrepreneurs to that particular market. Consequently, this prolongs the duration of the initial PM combination. This finding supports the argument that environmental ambition, i.e. “doing the right thing” for the environment, may be a non-rational factor that results in the escalation of commitments for a specific product or market, even when faced with poor or unclear performance indicators (Berchicci, 2005). Furthermore, an interesting finding is that in cases where the focus has been given to a specific product applicable in multiple segments, the case firms appear to be more alert to market signals, and make the shift to alternative markets segments easier. Apparently, how entrepreneurs identify an opportunity in relation to sustainability influences the ease of justifying sustainability claims for alternative markets. In other words, a high degree of change that entrepreneurs aim to bring into a specific market appears to increase the duration of (particularly the initial) PM combinations. On the other hand, product ideas that can potentially replace existing products in a diversity of markets appear to ease the justification of similar sustainability claims for alternative markets, at least in entrepreneurs’ mind.

In addition, the findings of this study suggest that the outcome of design experiments and stakeholder interactions influences the sustainability motivation of entrepreneurs over time, in particular the relative importance of social, environmental and economical goals. This case study suggests that balancing multiple objectives for new ventures, which are often constrained with resources, is a delicate act, as suggested by Hahn and his colleagues (Hahn et al., 2010). When the sustainability benefits of a particular product cannot be justified through design experiments, or when stakeholders are not willing to adapt the innovation, firms appear to redefine their value proposition in relation to sustainability. They may also prioritize financial goals over social or environmental goals for a certain period of time, until the innovation is developed to its full potential, and the firm survival is no longer perceived to be crucial.

8.2. IMPLICATIONS FOR THEORY

By adapting a process-oriented perspective, this study investigated how the product innovation process unfolds in new ventures, and how the founders' motivation in relation to sustainability influences the process. In particular, focus has been given to (i) the type of actions in explaining the evolution of PM goals, (ii) the patterns of PM iterations over time, and (iii) the factors explaining the differences in the patterns of product innovation. For this reason, this study has drawn on other studies within the innovation management literature and entrepreneurial decision-making, in order to extend the theory on the product innovation process in new ventures. A model is proposed that integrates the experimental learning approaches with control-based transformative approaches, and this model is applicable to both causal and effectual processes. In this way, the tension between learning versus transforming, or planning versus transforming is reduced; the case study demonstrates that firms engage in both learning and transforming activities, and to a lesser extent with planning activities. In addition, existing frameworks in the field of New Product Development that highlight formalized processes and well-planned activities, appear to be less suitable in the case of new ventures that face particular challenges and characteristics due to their size and newness. This is mainly due to the amount of time and financial resources that such information gathering and planning approaches require in the early phases. In that sense, the emphasis of learning and transformation in the descriptive model is legitimated by the case study findings, which demonstrate the significant role of design experiments and stakeholder interactions in driving PM goals. In situations of uncertainty, learning from experiments and co-creating with stakeholders help firms to progressively define their value offerings. This study contributes to the innovation management literature by offering an alternative perspective for the product innovation process. The descriptive model, therefore, is useful for studying the historical dynamics of the product innovation process over time.

Furthermore, by drawing on recent theoretical perspectives in the field of entrepreneurial decision-making and behavior, and applying them to the early phases of innovation process, the conceptual model developed in Chapter 5 provides opportunities to explain the behavior of firms; thereby shedding light on the differences among firms, i.e. adaptive versus exaptive. The conceptual model includes individual differences between entrepreneurs (i.e. level of expertise, motivation in relation to sustainability, prior knowledge and network), resource differences, differences in opportunities, and to a certain extent, institutional context differences (i.e. through the entrepreneurs perception of uncertainty). The conceptual model therefore provides a comprehensive picture of sources to explain the differences in firm behavior and innovation process.

In addition, this study contributes to the theory of effectuation by extending the dynamic model of effectuation through integrating the act of design and embodiment into the model. This study has observed that not only stakeholder interactions, but also design experiments have a significant role in the evolution of PM goals. Particularly in cases of higher levels of technological uncertainty, the definition of the PM pair appears to be primarily driven by design experiments. The negative or mixed outcome of design experiments are likely be the trigger for the development of new applications or shifts into new markets. In this process, the sustainability motivation of the entrepreneurial team, the feedback of potential customers and the resource position of the firms are important factors. In addition to this, design experiments appear to have indirect effects. When firms adapt an exaptive approach, design experiments are used instrumentally to create alternative solutions, and consequently influence the self-selection process of stakeholders, which may result in actual commitments.

8.3. LIMITATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

The case study approach adapted in this study has enabled an in-depth analysis of the product innovation process through detailed descriptions of the case narratives presented in Chapter 6. Despite this, the case study approach entails several possible limitations. First of all, this study has analyzed a limited sample of case firms, which limits the generalizability of the findings. In order to further research product innovation processes and validate the findings, a larger sample of cases among new ventures is recommended.

Although this study has benefited from following entrepreneurs and their ventures in real time for an average of three years, it mainly relied on retrospective data, which has implications for the accuracy and completeness of the data, particularly for the early phases of case firms. In order to deal with the retrospective bias, in addition to the interviews, this study has used a variety of complementary documents as data sources such as patents and websites, graduation reports and email conversations with the founders. In order to increase the accuracy and validity of future studies, following new ventures in real time with the use of ethnographic research methods would be a recommended.

In addition, this study has focused on the early phases of the venture development process. Consequently, analysis has been primarily descriptive, explorative and explanatory, with a focus on how and why firms engage in different processes. For this reason, it was not possible to evaluate the success or failure of the case firms, as well as the social and environmental consequences of the firms' innovations. At the end of the data collection process, the case firms were prepared for subsequent design experiments and stakeholder interactions, thus the definition of PM goals was still evolving. Furthermore, although some firms were successful in achieving their first sales, the firms' long-term success, as well as the social and environmental impact of products, are yet to be determined since these firms have not yet entered the growth phase. As a result, another limitation of this study was the limited analysis of the success and failure of the firms, as well as the social and environmental consequences of their products. A future ex-post study of the case firms may give insight into the consequences of different experimentation approaches in different conditions, resulting in the identification of 'best practices'.

Moreover, this study is qualitative and exploratory in nature in order to gain an in-depth insight of the innovation process in new ventures. Further research can improve the generalization of the findings by further testing the propositions through a quantitative research design based on a larger sample product innovation projects in new ventures.

A limitation of this study was its focus on sustainability-oriented new ventures, as the purpose was to investigate the influence of entrepreneurs' motivation. Therefore, a future comparative study on sustainability-oriented and commercial entrepreneurs might contribute to a better understanding of the influence of sustainability motivation and further fine-tuning the findings of this study.

Another topic for further research is the influence of personal characteristics on the product innovation process. Effectuation suggests that expert entrepreneurs are by default effectual, and novices are all over the spectrum of causal-effectual behavior. In that respect, personal characteristics play a role in explaining why an entrepreneur predominantly uses a causal or effectual logic, and consequently how product innovation proceeds. Future research might investigate the link between personal characteristics and the use of a particular logic and its consequences for the innovation process.

Additionally, the levels of uncertainty linked to an innovation have implications for the innovation process. Particularly in cases of high levels of market uncertainty, an effectual logic is more suitable (Sarasvathy et al., 2010). However, at the level of firm decisions, it is the entrepreneurs' perception of uncertainty that influences their use of causal/effectual logic (Reymen et al., 2015), and consequently their decisions regarding the timing and type of both design experiments and stakeholder interactions. Thereby, the gap between actual uncertainty and perceived uncertainty appears to be an important factor in explaining venture failure, requiring further research.

Finally, since the research interest in this study is on firm-level decisions, firm and individual-level perspectives have been taken as a starting point to explain the similarities and differences among new ventures' product innovation processes. From an alternative perspective, such as macro-level, other factors than those explored in this study might emerge. For instance, the institutional theory and multilevel design model of Joore and Brezet (2015) can contribute to further understanding of the product innovation process in new ventures. Although the influence of institutional and system level factors has been touched upon in case descriptions and analysis, in some cases through stakeholder interactions, further research is recommend on the influence of regulative, cognitive and normative factors, such as government support on certain technologies and products, shared beliefs of an industry on dominant problems and solutions, as well as cultural differences between countries (Scott, 2005).

8.4. IMPLICATIONS FOR PRACTICE AND RECOMMENDATIONS

Besides theoretical contributions, the findings of this study have implications for management and design practitioners. This study has focused on the early phases of sustainability-oriented new ventures that engage with new product development. The insights gained through this particular empirical setting are primarily interesting to new ventures, and to a certain extent, corporate managers in established companies who primarily practice planning approaches. Design practitioners interested in effectuation, which offers an alternative type of reasoning, and is arguably more intimately linked to 'design thinking' (Dorst, 2011), can also benefit from the insights of this study.

The findings of this study provide entrepreneurs, particularly novices, design practitioners and students who are considering starting a new venture based on a product idea, with theoretical understanding concerning the different type of decision-making logics and their behavioral implications for conducting design experiments. They can gain insight on the use of different decision-making logics, both simultaneously and interchangeably during the innovation process over time and under different conditions of uncertainty. This enables them to engage in design experiments with different purposes (i.e. instrumental versus goal-oriented) more effectively, and reduce uncertainty to a manageable level. This study provides the following recommendations to practitioners.

Combine sustainability vision with affordable small steps. The starting point and the motivation behind this study was to explore how the product innovation process unfolds within entrepreneurial settings that are motivated by an issue related to sustainability. The insights of this study reveal that the definition of a PM pair is fluid in the early phases. The initial assumptions are likely to be incorrect, optimistic and idealistic, and modified as the ventures engage in design experiments and stakeholder interactions. Consequently, sustainability measurement tools and methods such as Life Cycle Assessment, which represent a causal logic, might not only be effective, but might also jeopardize the limited resources of new ventures. Such tools, when applied in a non-streamlined way, appear to be more suitable in later phases of the process when ventures arrive at a promising PM combination. Thus, creating room for flexibility, experimentation and interactions appears to increase the learning effects in relation to sustainability, technical feasibility and market acceptance. For instance, the analysis of the cases demonstrates that in some cases, sustainability motivation appears to prolong the duration of PM pairs; while in other cases, firms make the shift to other markets easier and faster in order to get the commitment of stakeholders, create short term results and exploit opportunities as they emerge for short term revenue generation. The latter approach appears to be more effective for developing products to their full potential, thus demonstrating their functionality, and then shifting back to the intended market where the sustainability benefits are expected to be higher. In other words, combining a strong vision for sustainability with affordable small steps in line with this vision might prevent firms from the risk of mission drift and loosing their sustainability goals over time. This appears to be a more suitable approach for the creation of successful products and business ideas, as well as increasing their sustainability benefits.

Establish an understanding of uncertainties. The results of this study show that ventures are confronted with different levels of uncertainty. Although effectuation is suggested to be a more effective type of reasoning in situations of uncertainty (Sarasvathy et al., 2010) and in the early phases of the product innovation process (Berends, Jelinek, Reymen, & Stultiëns, 2014; Reymen et al., 2015), this case study demonstrates that firms might still prefer to use a causal logic or vice versa. The rationale behind this appears to be two fold: 1) deliberate choice, and 2) a lack of awareness on the degree of uncertainties. When firms deliberately choose for a causal logic and engage in design experiments without much stakeholder interactions, in an effort to arrive a proof of concept, slack resources might help; however, firms might lock in a specific PM combination for longer periods of time and eventually failure might be inevitable. Furthermore, a lack of awareness on the technological and/or market uncertainties might result in an approach that does not fit the type of an opportunity. Although scholars highlight the difficulty of evaluating the level of objective uncertainty (Reymen et al., 2015), "decomposition of the overall venture management problem into sub-problems is feasible and natural to managers, that a qualitative assessment of knowledge gaps and vulnerability to unknown unknowns is possible" (Loch, Solt, & Bailey, 2008). Asking questions such as "what are my knowledge gaps?", "what aspects of the future are predictable and what aspects are not?" and "when planning is feasible and relevant?", can therefore help in identifying uncertainties, and selecting the suitable approach to product development process.

Focus on available means: motivations, capabilities, knowledge and network. Focusing on available means does not necessarily mean engaging in exploitative activities as opposed to explorative activities. While exploitation is often associated with incremental innovation, as it builds on existing knowledge and capabilities of a firm, the results of this study show how firms can build on existing means, yet develop radically new products for both the firm itself and its customers. Focusing on means enables firms to take immediate actions in an affordable way, and to achieve short-term results that can be exposed to the external world early in the process for feedback and acquiring new means.

Design experiments affordably in order to communicate to external stakeholders. Investors and funding organizations often demand a working prototype and/or a business plan in order for a firm to justify the existence of a demand, that the firm is capable of creating what product it intends to develop, and is aware of the financial and non-financial means necessary for this development. This mirrors a causal logic to venture development process. However, this study shows how firms create demand and develop new products with affordable small steps, in partnership with others and without relying on extensive external resources. In addition, exposing ideas early in the process facilitates interactive problem solving, which "can bring novel perspectives on the problem and save time" (Kopecka, Santema, & Buijs, 2012). Therefore, a final recommendation to new ventures is: do not wait until you have a working prototype, but engage with stakeholder interactions as early as possible. Design experiments and stakeholder interactions reinforce one another.

8.5. IMPLICATIONS FOR DESIGN EDUCATION AND RECOMMENDATIONS

Design educators can also benefit from the findings of this study. Design tools and methods taught in design schools, including the Faculty of Industrial Design Engineering in Delft (see Kersten et al., 2015; 'Context Variation by Design' for an exception), often represent a causal logic, are goal-oriented and based on prediction and analysis. One rationale behind this is that the primary focus of design schools is large companies; new ventures are often overlooked in the current curriculum. The findings of this study might inspire design educators to develop new perspectives and didactic materials that can address different organizational settings under different conditions of uncertainty. Although it was not the main focus of this research, examples of such 'designerly' tools developed within the context of this study are presented in Appendix C and D. These tools might offer design students an alternative way to develop new products and ventures, representing a creative action based approach as advocated by 'design thinking' scholars. The following recommendations are proposed for design educators.

Provide students with tools and methods for unpredictable situations. The rational innovation models, such as the New Product Development, typically assume that a problem, such as a customer need, is known at the outset of the innovation process and a solution can be identified through a goal-oriented step-wise process, by means of various forecasting tools and methods. However, in situations of uncertainty, forecasting future developments is a challenging task. The insights from this study demonstrate that products and markets co-evolve from the process itself, through actions taken by the entrepreneurs. Design educators can provide students with examples of such unpredictable situations, and a set of tools and methods to address them.

Facilitate students in learning alternative ways and encourage them in taking prompt action. Effectuation suggests an alternative way of developing a new product and implies a different set of actions, in a different sequence in comparison to causation. Its implications for design experiments have been extensively discussed in this thesis. Design educators can make use of the insights from this thesis in facilitating design students to learn what alternative actions they can take in developing new products, and encourage them to take prompt actions. An example of such facilitation method is illustrated in Appendix C, 'play effectual'; a game developed to introduce students into effectuation in a fast and joyful way, in order to make them aware of such alternative actions in developing a new product and a new venture. The game consists of 25 causal and 25 effectual actions, as well as a playing board, which represents the first year of a business development process. The participants are asked to develop their PM ideas by choosing 25 actions over a one-year period. At the end of the game, participants can evaluate which logic they have primarily used, based on the actions they have selected. Such tools can encourage students to take prompt actions, since they provide an overview of alternative actions in a short time frame, and enable students to engage with learning by doing, even though the game only simulates the venturing process.

Provide students with means-oriented methods and tools. The majority of approaches and methods in design schools are goal-oriented, representing a causal logic. Focus groups, trend analysis and SWOT analysis portray good examples of such tools that define step-by-step procedures for information gathering and systematic analysis, that enables a firm to 'position' itself in a given competitive environment. Although SWOT analysis can be considered as a means-oriented tool, as it focuses on the strengths and weakness of a company, yet its objective is to establish a predefined goal at the outset of the innovation process before committing any significant resources to a specific PM combination. Furthermore, it is a time and resource intensive activity. On the other hand, effectuation implies being flexible with the definition of PM pair and using a set of existing means to promptly define an actionable initial PM pair, which is expected to alter along the process. Appendix D provides a workshop format, 'effectuation on the roll', designed based on the principles of effectuation (van Sinderen, 2015). The first step of the workshop portrays a good example of a tool that illustrates how participants can develop an initial set of actionable opportunities, based on their existing means in a time frame of 20 minutes. Additionally, causal oriented design approaches can be transformed into less resource intensive and/or streamlined methods and tools.

Encourage students for stakeholder interactions. The insights of this study show how stakeholders have an important role in driving the PM goals. When it comes to making business, what matters is finding the potential clients and partners who are willing to commit resources to a venture's offering. As a result, design educators can encourage students to engage with stakeholder interactions as early as possible, even before product ideas materialize into design experiments. For example, the third step of the 'effectuation on the roll' workshop (Appendix D) encourages stakeholder interactions by given the participants the assignment of calling two contacts from their existing network to discuss their intended product idea (van Sinderen, 2015). These kinds of methods help students to expose their ideas early to the external world.

8.6. IMPLICATIONS FOR POLICY AND RECOMMENDATIONS

Although the climate for new ventures in the Netherlands currently lags behind countries such as United States, France, Canada and the United Kingdom, according to the Chamber of Commerce (2014) the number of entrepreneurs starting businesses in the Netherlands was over 150.000. This is an increase of 13% in comparison to 2012. The Dutch government has recently put emphasis on the ways to improve the climate for new ventures. As such, insights from this study are of interest to policy makers, as well as the intermediary organizations that provide support to new ventures. The following recommendations are suggested.

Promote sustainability within innovation and business/new venture policies. By promoting sustainability and making information regarding trends and sustainability public, the government can empower entrepreneurs and young people, and enable them to imagine new possible ends based on the combination of this information and the means available to entrepreneurs.

Focus on people rather than business plans. Innovation support organizations, as well as investors and funding organizations often demand a business plan, which represent a causal logic, prior to funding an innovation project or a new venture. Writing a business plan is a time and resource intensive activity, particularly considering the definition of PM is fluid in the early phases of the business development process. The initial assumptions and predictions are often incorrect and optimistic, which makes the calculations of the upside potential of an idea irrelevant. Instead, focusing on people and their existing set of knowledge, competences, network and how well they use these means, as well as the factors (entrepreneurs perception, expertise and motivation) proposed in the conceptual model appear to be better questions to ask entrepreneurs and better predictors of venture success.

Fund ventures in small installments rather than one-time large investments based on business plans. The availability of resources is likely to stimulate the use of causal logic, particularly among novice entrepreneurs (Sarasvathy, 2008). Funding ventures in small installments based on short-term outcomes mirrors the principle of 'affordable loss'.

Encourage for experimentation and stakeholder interactions. The findings of this study demonstrates that firms might need to create a demand first, as customers may not be familiar with new products and articulate their needs in relation to them. By encouraging entrepreneurs for experimentation and stakeholder interactions, support organizations can help new ventures create demand before fully committing to a specific PM combination.

Lastly, the mentors in intermediary organizations such as incubators that support new ventures intensively can benefit from the recommendations suggested for design educators as well as the tools presented in Appendix C and D.

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Appendix A:

Interview topic guide

Quality and quantity of each over time

Key product concepts (product ideas committed)
When and for how long were time and resources committed to particular product ideas?

Key target markets (market segments committed)
When and for how long were time and resources committed to particular segments?

Key stakeholders (entrepreneurs, shareholders, investors, partners, customers, suppliers)
What type of means did each bring to the venture? What did they demand in return?

Key design experiments (models, prototypes, early versions)
When, how and with what drivers were these experiments conducted?

Other activities of the founders (business plans and other documents written, board meetings, product presentations, research, etc.)

Financials (type and quantity)

Expectations and assumptions (perceptions of feasibility and viability)

Motivations in relation to sustainability

Entrepreneurs' background and previous activities before firm founding

Appendix B:

Coding scheme and illustrative quotes

Theoretical construct	Indicator / operational measure	Illustrative quote
Product-market iteration	Definition of the subsequent product concept/application a firm engages in for a particular market segment	**Sustainable Dance Club: “***The clubs are the primary target group. But because our current flagship product is the dance floor, there many organizations worldwide who ask us to rent or sell the dance floor. They are organizations who want to do a marketing campaign and link themselves to sustainability but also expositions about new energy and human power. We also sell to those customers.”* **Vrachtfiets:** *“The idea was that we would own the bikes and rent it to service providers, like a local hotel or camping. They would rent it to their own customers.”* **Solar Dew:** *“We had different product-market combination experiments on the side, amongst others wastewater evaporation. So, Oman was wastewater for crops, wastewater evaporation like heavy metals, to get rid of the water in a low cost way. If you have a refinery, you do maintenance, you need to clean it.”*
A shift in product-market combination	Decision to develop a different product concept/application and/or probe in alternative market segments	**Evening Breeze:** *“Five years ago it was completely normal that somebody would walk into your bed store and say ‘I am looking for a new bed’. Then you would ask them, ‘what kind of bed are you looking for and what budget you have in mind?’ They would just pick a bed of 10-15,000 € and go out. You do not see that anymore. That’s why we moved a little bit away from the consumer market and we just wait till this temporary issue is over. Then we move back in.”* **Sustainable Dance Club:** *“At the beginning we had the idea that selling would be quite important, like the bar systems, systems to use the heat in a good way, also the dance floor, the lighting system. It was already quite soon when we started to develop the floor that we were aware of the rental market. That’s also why it [the floor] was a modular system; you can build in different shapes and sizes. So it was already in our head but we were forced by the market because it was too expensive to sell … for the market we had initially in our minds. Actually we are hardly doing anything for clubs.”* **Solar Dew:** *“After we lost Shell, we decided to stop this concept. But we could only decide to stop this concept if we had a next one or else the whole project would die. So we did parallel research after the first trials in Oman and the publication was successful. We decided not to make the 100 by 100 meter collector.”*
Design cycle	Embodiment of a product idea into physical applications in a controlled environment (e.g. trial, lab/field test) or in real markets (e.g. probe)	**Evening Breeze:** *“Everything worked out but it was not a real prototype. It was like a functional prototype, like I could demonstrate that it works, that the air is really going through the textile duct. It worked but you could not use it for tests. So it was just to demonstrate the function and have the perception of the dimensions.”* **Vrachtfiets:** *“After IKEA, we were building the one-person bicycle for the municipality. So it was the third for them. … This is the first one-person bicycle.”* **Solar Dew:** *“We have done an ultrasonic trial on a line, and we are going to do an ultrasonic trial on a roll with the manufacturer. Because testing it on a line is something else … on a roll-to-roll process the parameters are completely different.”*

Theoretical construct	Indicator / operational measure	Illustrative quote
Driver for design cycle	Reason to engage in a design experiment	**Evening Breeze:** *"It was more to find out if it would really work in the real situation. … [to test] the working principle. So we had three beds made, we put them there, we tested them with the real climate there."* **Solar Dew:** *"Then immediately we got this early customer trial, which was important to get finance, momentum and research development money. Plus the fact that then you have a committed customer. … And by this way you can see 'is this market realistic? Yes or no?'"* **Vrachtfiets:** *"We tested also the business model. It was not only about the prototype. We tested how people use it, what they thought of it, how it would work at campsites. Because, the idea about Vieco is that you rent it at places nearby the train station, so you can drive with the whole family to the recreational area."*
Type of design cycle	Type of the physical application on the basis of the degree of its fidelity (e.g. mock-up, lab test, field test, (full-)scale model, working prototype, early version)	**Solar Dew:** *"From phase 1 to phase 2, you are talking about larger scale because of huge quantities of water that had to be processed and agricultural fields. So we were asked to make a 50m3/day solar collector. Based on our field trials in Oman and Canary islands … we could make 50m3/day if we made a solar collector of 100 by 100 meters in the middle of the desert with stainless steel gutters, instead of earth. Stainless steel is expensive."* **Sustainable Dance Club:** *"Then our new designer integrated the two. Because the top layer was separately designed from the mechanical part and then we had our own designers who integrated it, made it one product. We call this the first version because that was more industrial, ready for real use."* **Evening Breeze:** *"This was the first 1:1 model we tested in the climate room of TU Delft."*
Stakeholder cycle	Stakeholder interactions that a firm engages (with or without commitment)	**Evening Breeze:** *"We first sold to a resort 1,5-2 years ago. We said once we got our first, the rest will follow very soon. That just did not happen as fast as we thought. We sold only to four resorts after that one. One villa took three; the other one is testing with two; the other one took just one."* **Sustainable Dance Club:** *"This was USA in December 2008. Because the product development, from here to here, was partly paid by Absolut Vodka. Because they scout on new ideas; they want to be the first with new art. And now they have a focus on sustainability, they said 'we want to be the first one to bring it to the market'."* **Solar Dew:** *"So 2004 was basically polymer production in order to continue trials and a new concept. And Business Factory was financing."*

Theoretical construct	Indicator / operational measure	Illustrative quote
Driver for stakeholder cycle	Reason to engage in a stakeholder interactions	**Solar Dew:** *"So the main thing here is trying to survive and meet the Shell requirements. But we knew that we had to make sure that the technology developed to its full potential."* **Vrachtfiets:** *"We had this idea, we wanted to built a prototype and we needed money. But it would cost us 10,000 € to build it. So it was pretty expensive. … We first got [the money] from STUD Fonds and because we already had a little bit of money we could say to the other one 'we already have money, there are already people involved'. … So this was how we tried to get the total amount of money."*
Type of stakeholders	Type of stakeholders interacted, leading to commitment or not (e.g. customers, investors, partners)	**Evening Breeze:** *"In the Netherlands, we decided to team up with Eastborn, which is the biggest bed manufacturer in the Netherlands.* **Solar Dew:** *"So at this time, in 2006, they project was stagnating. Frank had seen that it had potential … and discussed it with Floris [investor]. …So they bought the patents."* **Sustainable Dance Club:** *"This was the first moment that we could deliver a floor or already sold the floor. This was September 2008, Club Watt opening."*
Type of opportunity	Degree of technological uncertainty on the basis of patents a venture possess, the degree of effort and time to necessary to develop a working prototype, the degree of uncertainty expressed by the entrepreneurs	**Solar Dew:** *"We know which variables we want. We want good water vapor permeability, good pressure resistance, good flexibility, good flatness. We know all the variables but because we have never made the trial with the coating, we do not know which one is more important. We also do not know how materials are going to behave, especially in the long term."* **Sustainable Dance Club:** *"Actually at the opening of Club Watt the floor was not working. … We went to the shop, we bought springs, screws and foam and a few days before the opening; we were screwing the floor together. It didn't work. We used the plugs, electricity. So we just simulated."*

Theoretical construct	Indicator / operational measure	Illustrative quote
Entrepreneurs' perception of uncertainty	Assumptions and expectations of entrepreneurs in terms of technical feasibility and market viability of a product-market idea, as well as the financial uncertainties	S**olar Dew:** *"In those days we were not sure what the scope of the technology was. Could there be other product-market combinations?"* **Solar Dew:** *"The stage which we are in right now is very unclear in terms of the results. A lot of governments, NGOs do not like this phase; it is too risky. Governments willing to invest in projects where you have a proven technology in Holland and you want to go to India. … it is difficult to find subsidies in the area between a proven technology and a commercial technology because that's the place where the risk is."* **Sustainable Dance Club:** *"What already cool is, here was already the market. When they launched the concept just by talking about it, people already started calling. So there was nothing; there was only a movie, sketched and people and the market already started calling, 'we want to but the floor, we want to see the floor'. We had to sort of temper the enthusiasm."* **Vrachtfiets:** *"The current issue is that a lot of people are interested right now, but we do not yet have the final product. That's also has to do with finance. … we are still dependent on out customers to buy a Vrachtfiets and then we have some money to develop the vrachtfiets."*
Entrepreneurial expertise	Degree of prior venture experience in terms of number of years and ventures founded	**Evening Breeze:** *"Five years ago, Tim and Nico, working as eco consultants on curacao, noticed that resorts were complaining about energy use and costs."* **Sustainable Dance Club:** *"I have set up clubs, certain combinations. … [I] have a background in clubbing. I have set up Off_Course, Rotterdam electronic festival, things in nightlife."* **Vrachtfiets:** *"I graduate in Mat 2010. Onno graduated one month before me."* **Solar Dew:** *"… they [brainstorm sessions] happened at the level of corporate research director, which is important, because he could immediately take action."*
Resource position	Financial resources available to a venture over time	**Evening Breeze:** *"Evening Breeze is an independent company for two years, no subsify. I think we just got to the point from where Evening Breeze costs money every month to a point Evening Breeze start making little money. So we are just at the tipping point. So more freedom to make decisions."* **Solar Dew:** *"The team working on it received certain amount of money to continue the development for one year. Because Akzo said 'you have been working on it so hard, here is some amount of cash, do with it what you like and try to get this project off the ground'."* **Vrachtfiets:** *"Agentschap, this is the government. This is one of our main payers. This is why we still live."*

Theoretical construct	Indicator / operational measure	Illustrative quote
Sustainability motivation	Degree of priority of social and/or environmental goals, and market ambition of the entrepreneur (e.g. niche versus mass market)	**Sustainable Dance Club:** *"The ambition is to set up a worldwide network of sustainable dance clubs. … We want to have clubs that are really a showcase and have an appeal to a large public. The other goal is to reach people, young people in those clubs. So it should have a snowball effect; those clubs in a number of cities in the world. They should inspire other clubs to start, to be more sustainable."* **Sustainable Dance Club:** *"We were too idealistic, focusing on the club owners instead of focusing on the floor. So for them [the team as of 2008] it was much more about creating sustainable clubs for the club owners. Trude [the business development director] had done a thorough analysis of the whole organization [Club Watt] and how they could integrate sustainable purchasing in their organization. So the organizational aspect was very important and it really took a long time to accept that the floor was the thing. If we would have shifted earlier, maybe it would have been different."* **Evening Breeze:** *"We really wanted to sell these four-poster beds to resorts as far away as possible. And I still think that's the most interesting market segment because there the value of the product is huge, in terms of sleeping comfort and environmental impact. But we are now already more successful with the second product which is launched not even a year ago."* **Solar Dew:** *"The intention was to develop it for BoP … the main reason is just to do something back to the world. I am not Florence Nightingale but the idea, ok, that helps. I never had the idea that we earn a lot of money on it. It was just an investment, or subsidizing. If it will be successful, perhaps we will earn something back but it is not the idea to make a bog earning business of it."* **Vrachtfiets:** *"All the students coming from Amsterdam, Groningen, Limburg to Delft and then of course they need a new couch, they need to buy something from IKEA and they ask their parents to come to Delft to transport this couch from IKEA to their homes which is only one kilometer. This is not sustainable."*

Appendix C:

Play effectual

'Play effectual' is a simulation game that has been designed to explore the effectiveness of games to teach effectuation. The aim of the game is to introduce effectuation to an audience that is more familiar with causal approaches. Although both causal and effectual approaches might be adopted on the basis of different levels of uncertainty linked to an opportunity, the game is designed to favor an effectual approach in order to create an atmosphere for discussion among the participants.

The game is designed to simulate the first year of a business development process, and consists of a playing board and number of actions. A behavioral approach has been adopted for the game design, i.e. the cognitive aspects of causation and effectuation have been translated into a number of observable actions (see section 3.4). Based on a review of the foundational papers on effectuation, as well as the studies of Fisher (2012) and Chandler et al. (2011), 25 casual and 25 effectual actions have been identified that are likely to be undertaken in a venture development process. The actions are randomly numbered and provided on small cards, in order to allow game participants to decide on a number of actions for their business development process (Figure C.1). The game allows the use of 25 actions out of a total of 50 actions.

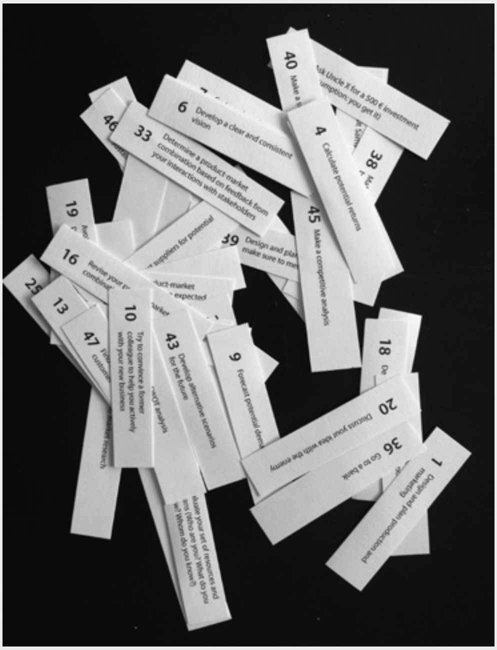

Figure C.1. Action cards used in the game

The playing board (Figure C.2) represents the first year of a business development process, and is used for game participants to stick their preferred actions over time. Additionally, the board is divided into three four-month periods in order to identify the sequence of actions undertaken by participants.

The game starts with an assignment that asks participants to develop a new venture based on a sustainable product idea. During the game, the participants are given the role of entrepreneurs, and are asked to use the actions on the playing board when developing their business ideas. The game design allows participants to make groups of two, which are provided with a €2500 budget as input for their business. The expected outputs of the businesses are stated as a €100,000 budget, a working business, and an outstanding network.

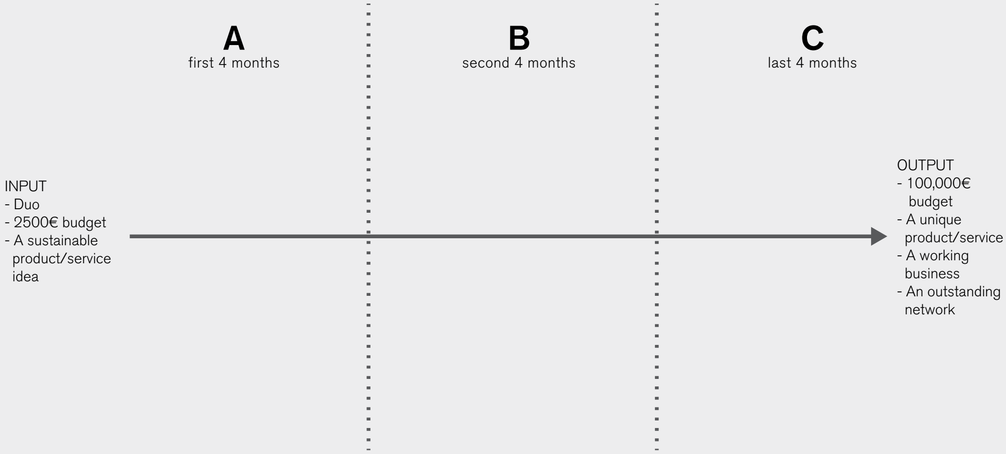

Figure C.2. The playing board

For the scoring, an 'ideal' effectual start-up process is developed, which is compared with the playing board of all participants at the end of the game. Although there does not exist an ideal sequence or timing of actions, and every process might look different depending on the uncertainty involved and the level of entrepreneurial expertise, the ideal process developed consisted only of effectual actions used in the different phases of the process. This ideal process is used when scoring the processes of participants.

The game has been tested on several different occasions with students and professionals (Figure C.3). Preliminary findings suggest that the game was successful at creating awareness on the existence of an alternative approach, and also at reaching specific learning objectives in relation to effectuation principles. Instructors teaching effectuation could consider gaming as an additional educational resource to get students -but also entrepreneurs and other stakeholders- engaged in effectual decisions and actions. In addition to the game being used as an awareness tool, it also provided insights into the profile of the students/participants and their causal/effectual behavior over time. Therefore, instructors can use the game in assessing the learning needs of students, as well as the planning of their didactic materials.

Figure C.3. Game tests

Appendix D:

Effectuation on the roll

'Effectuation on the roll' is a workshop format that has been designed to teach the principles of effectuation (see section 3.3.2) in a fast, joyful, and effective way to those who are not familiar with the concept of effectuation. The workshop consists of a paper roll (Figure D.1) that emphasizes the iterative nature of the venture development process. After completing the first cycle, participants are encouraged to conduct a second a cycle, based on what they have learned from the first cycle. The paper roll consists of a number of small exercises for each principle of effectuation: bird in hand, affordable loss, crazy quilt, and lemonade.

Figure D.1. The paper roll

The steps of a cycle is as follows:

Step 1 Develop a number of actionable opportunities (bird in hand)
In the first step participants work with a means-wheel (Figure D.2), in order to develop a number of business ideas. The wheel consists of three layers, in which participants can write a set of means available to them. The inner circle gives direction to the opportunity. The participants are asked to choose an umbrella term such as sustainability, education, or arts; this term is the basis of which they would like to begin their business. The wheel is made up of smaller inner wheels, so that the participants can rotate the layers of the wheel to align words, and combine different means for developing alternative opportunities.

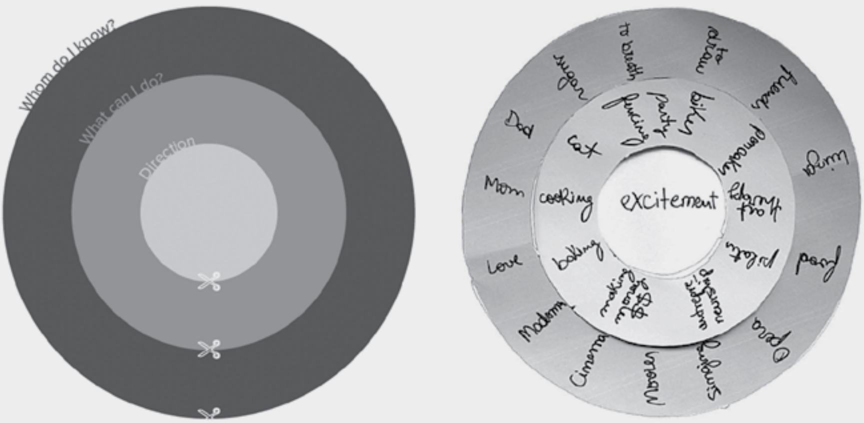

Figure D.2. An empty (left) and filled in (right) means-wheel

Step 2 Pick the best opportunity (affordable loss)
The opportunities that were identified in the previous step are ranked in step 2 based on the affordable loss principle. Accordingly, a number of matrices (Figure D.3) are provided in which the participants can evaluate their ideas based upon, for instance, the time and financial resources required, the level of market and technological uncertainties, and perceived social and environmental consequences. During this exercise, the participants are encouraged to answer the questions: “How much time and money are you willing to spend, and can afford to loose?”

Figure D.3. An empty (left) and filled in (right) evaluation matrix

Step 3 Interact with potential stakeholders (crazy quilt and lemonade)
This step forces participants to move into action and interact with potential stakeholders. The participants are asked to leave the room (literally) and interact with the outside world. For this purpose, an overview of potential stakeholders, and how the participants could approach them are provided (Figure D.4). They are asked to contact at least two potential stakeholders (e.g. another participant in the workshop or someone outside the workshop) for feedback, information, advice or support. In this step, they also get the chance to experience what it means to be confronted with unexpected contingencies, and revise their business ideas based upon the feedback they have received.

Figure D.4. An overview of stakeholders to contact

Step 4 Report and discuss findings (reflecting and lemonade)
The last step of the cycle is an evaluation of the feedback from stakeholders that participants had contacted (Figure D.5). In this step, participants discuss their approach to stakeholder interactions, the type of stakeholders they contacted, and the feedback they received. Finally, they make a pitch of their business based upon this feedback.

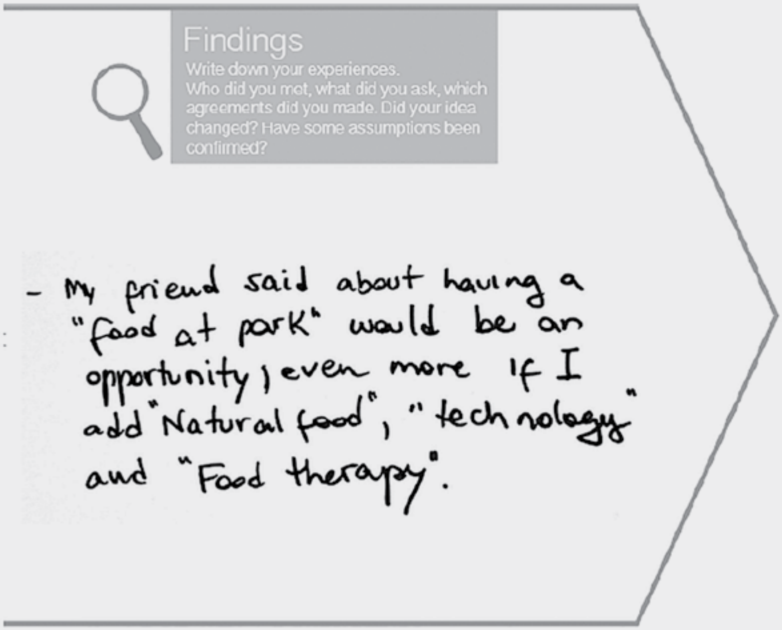

Figure D.5. An example of a participant's reflection on the feedback

Once all the assignments in each step have been executed, the first cycle of the workshop is completed. On the basis of the learning and feedback from the first cycle, the participants are asked to adjust their goals and start a second cycle; however, in this cycle the wheel looks different with additional set of means.

The game has been tested on a number of occasions with students and professionals. Preliminary findings suggest that the game was a successful awareness tool in conveying the effectuation message; the players enjoyed it and found it educational. The game introduced the players in a fast, joyful and effective way to the theory of effectuation. Besides learning effectuation as an alternative approach, the participants could directly apply it, and learn what the implications are in practice.

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Duygu Keskin
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About the author

Duygu Keskin was born in 1979 in Antalya, Turkey. She obtained her Bachelor's degree in Environmental Engineering and Master's degree in Industrial Design at the Middle East Technical University in Ankara. During her Master's studies, she visited the Design for Sustainability program at the Faculty of Industrial Design Engineering of Delft University of Technology as an Erasmus exchange student. For her Master thesis she studied public use bicycle systems from a sustainable mobility and product-service system perspective, and received her Master's degree in 2006.

After completing her Master's studies, Duygu worked as a researcher at the Faculty of Industrial Design Engineering, and was involved in several European projects at the intersection of design, sustainability and entrepreneurship, such as 'Cleaner Production for Better Products' focusing on SMEs in Vietnam and Cambodia, 'Learning Network for Sustainability' developing didactic materials within an Asian-European multi-polar network, and 'Environmental Market and Innovation Development' (Ecomind) providing company specific support to small and medium sized enterprises in the field of design, business and networking, with a focus on Dutch, French and British firms and startups.

In 2009, Duygu started her PhD research on the dynamics of product innovation processes in sustainability-oriented new ventures at the Design for Sustainability program at the Faculty of Industrial Design Engineering of Delft University of Technology. Next to her PhD, her research interests also include serious gaming for design and entrepreneurship education. She has developed a range of games based upon the findings of her PhD research for teaching alternative decision-making theories to design and entrepreneurship students.

Selected list of publications

Küçüksayraç, E., Keskin, D., & Brezet, J.C. (2015). Intermediaries and innovation support in the design for sustainability field: Cases from the Netherlands, Turkey and the United Kingdom. *Journal of Cleaner Production,* 101, 38-48.

Keskin, D., & Brezet, J.C. (2015). Gaming as an Approach to Convey the Effectuation Message. Working paper.

Keskin, D., Wever, R., & Brezet, J.C. (2014). *Dynamics of product innovation in new ventures.* Paper presented at 3rd Effectuation Research and Teaching Conference, Enschede, 8-9 December 2014.

Keskin, D., Wever, R., & Brezet, J.C. (2014). Developing New Product and Services in Entrepreneurial Context. In C. Vezzoli, C. Kohtala, A. Srinivasan (Eds.), *Product Service System Design for Sustainability* (pp. 239-249). Cheffield: Greenleaf.

Keskin, D., Diehl, J.C., & Molenaar, N. (2012). Innovation Process of New Ventures Driven by Sustainability. *Journal of Cleaner Production,* 45, 50-60.

Keskin, D. Diehl, J.C., & Molenaar, N. (2011). *Use of generative techniques as an approach in facilitating sustainable innovation in small firms.* Proceedings of Innovate through Design - 18th International Product Development Management Conference, Delft, 5-7 June 2011.

Molenaar, N. Keskin, D., Diehl, J.C., & Lauche, K. (2010). *Innovation process and needs of sustainability-driven small firms.* Proceedings of Knowledge Collaboration & Learning for Sustainable Innovation, ERSCP-EMSU Conference, Delft, 25-29 October 2010.

Keskin, D., Diehl, J.C., & Brezet, J.C. (2010). *Teaching PSS in business practice: A win-win-win approach.* Proceedings of Knowledge Collaboration & Learning for Sustainable Innovation, ERSCP-EMSU Conference, Delft, 25-29 October 2010.

Keskin, D., Brezet, J.C., & Diehl, J.C. (2009). *Commercializing sustainable innovations in the market through entrepreneurship.* Proceedings of the 1st CIRP Industrial Product-Service Systems (IPS2) Conference, Cranfield University, 1-2 April 2009.

The role of innovation in bringing about the necessary change for the sustainability of the planet and future generations is widely acknowledged among academia and practice. Sustainable innovations require organizations to design and develop new products, services and markets that transform the current practices in society while both decreasing environmental impact and increasing social welfare. Within the context of sustainability and business, new firms are increasingly recognized as candidates of creating innovations necessary for sustainability. Sustainability is an inherently uncertain journey into the future and entrepreneurial action is driven by uncertainty. Despite this recognition, little is known on how new ventures actually engage in this journey. How does the entrepreneurial context influence the decision-making in relation to new product development and sustainability? What are the implications of sustainability motivation for the innovation process? How the product innovation process unfolds within entrepreneurial settings motivated by an issue related to sustainability is the central question of this study.

New ventures are certainly not miniatures of large organizations. They possess distinct organizational settings and decision-making processes. On the one hand, they are seen to be more advantageous in innovation due to their flexible decision-making process, which enables them to quicker respond to the dynamics of industry environment. On the other hand, they are confronted with high levels of uncertainty associated with liabilities of being new and small. New ventures often do not possess the resources and capabilities necessary for bringing innovations to the market. Furthermore, in the case of sustainable innovations they face the challenge of demonstrating and justifying the sustainability benefits of new products to customers and stakeholders. Considering these challenges, new ventures are often not able to identify a promising product-market combination at the outset of the product innovation process, and instead progressively define their business idea. The objective of this exploratory study is to gain a profound understanding of this process: (1) How can the product innovation process in new ventures be described? (2) What explains the similarities and differences among the product innovation processes of new ventures? (3) How does the sustainability motivation of the entrepreneurs influence the product innovation process?