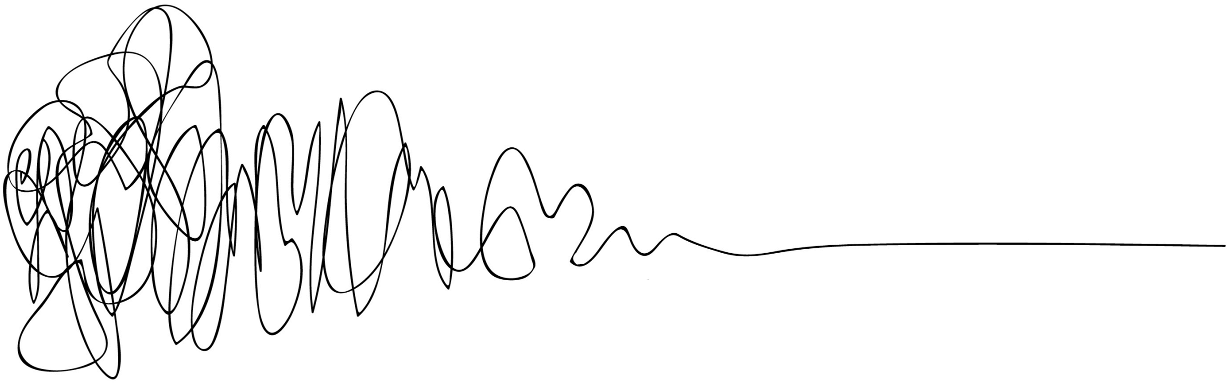
STRUCTURING THE FUZZY FRONT END OF NEW PRODUCT DEVELOPMENT

A CASE STUDY FOR A MODEL IN DISRUPTIVE INNOVATIONS IN BIOTECHNOLOGY



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"Everything is vague to a degree you do not realize

until you have tried to make it precise."

- Bertrand Russell

This thesis contains confidential information

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EXECUTIVE SUMMARY

Research problem: the fuzzy front end of new product development in discontinuous innovations at the DSM Innovation Center (Business Incubator)

New product development is a time- and resource-consuming endeavor, which encompasses many uncertainties when it involved the development of discontinuous innovations. These uncertainties (related to market and technological conditions) are mostly present in the earliest phases of development: the fuzzy front end. The Business Incubator within the DSM Innovation Center focuses on the identification of discontinuous innovations that have the potential to become a corporate venture within the organization. The fuzzy front end is where the majority of activities is situated. The problem faced by the Business Incubator is that currently, the fuzzy front end process is unstructured, which is caused by various aspects. First, projects tend to not move in compliance to the phase the projects are in, meaning that the activities and deliverables for the current phases are not consistent. Second, the organizational roles within these phases and activities are not clearly defined, especially the roles in the decision-making process of the fuzzy front end. As a result, projects are assessed as economically viable, while later on in the process the project is shut down when knowledge comes to light, which should and could have been known in earlier stages. Therefore, the Business Incubator is in need of a 'best practice' for the fuzzy front end, where activities and deliverables are clearly defined, resulting in a reduction of uncertainties in a highly uncertain environment.

The existing literature on new product development and the fuzzy front end presents a variety of models for this stage of development. These models are insufficient for the Business Incubator due to several reasons. First of all, all the models presented in literature are based on the development of incremental innovations, where the amount of uncertainties in terms of market and technology is low. Second, steps of the fuzzy front end are described, but the models lack a clear description of information needed in each phase and deliverables to be met. Third, no reflection is considered on an actual implementation into organizations, implicating that decision-making roles are not part of the models.

Research goal and the main research question

The main goal of this research was to develop a structured fuzzy front end model for the Business Incubator of the DSM Innovation Center, which would be suitable for the assessment of discontinuous innovations. The design of this model builds upon existing models from literature and insights in the decision-making process taking place at the Innovation Center. A list of requirements is set with which the model needs to comply, which were the following:

1. Uncertainty reduction in both market and technology
2. Strategy alignment
3. Decision-making roles division
4. Ease of use
5. Flexibility
6. Applicability at DSM

Moreover, insights were gained into the types of information (or assessment factors) that are important in each stage of the designed model, which provided a consensus and a consistent way of performing assessments of innovation projects. Literature is scattered with types of information on both market and technology aspects, but a list of these factors for the fuzzy front end stages does not exist. Besides designing the model with its list of assessment factors and allocated decision-making roles, this thesis strived to make recommendations for the implementation of the model into the organization. The main research question for this study was as follows:

"In what way can the fuzzy front end for disruptive biotechnological innovations be structured while highlighting the relative importance of assessment factors for each phase?"

Research approach

The main research question was answered by first conducting a literature study on the fuzzy front end of new product development. This study yielded insights into the types of uncertainties that are involved in innovations, in particular discontinuous innovations, as well as the different levels of uncertainties and their impact on business. Moreover, a list of assessment factors was obtained, which serves as the basis for the types of information that are needed during assessment of new product development projects. Finally, through this study an overview was obtained over the currently existing fuzzy front end models, together with their strengths and points of attention. From these models, three were selected for consideration in designing the structured fuzzy front end model.

In order to obtain more insights into the current fuzzy front end process within the Business Incubator and the decision-making process associated with the fuzzy front end, 7 high-level experts were interviewed. These interviews yielded an overview of the current steps that are undertaken within the fuzzy front end, while also highlighting the strengths and weaknesses of the current process. Furthermore, insights were gained into the decision-making process, which yielded in the allocation of decision-making roles to the stakeholders of the process.

After assembling the model based on the literature study and the interviews, a panel study was conducted in order to gain insights into the types of information needed in each phase of the yielded model. The list of factors gained in the literature study was used as a starting point. In three rounds, 15 panel members voted for factors that they considered as most important for each phase.

The evaluation of the obtained model and assessment factors was performed by positioning a currently running case into the model. This case considered a feasibility study on a novel group of a bio-based compound category. The feasibility of this innovation projects was assessed by conducting the activities and collecting the needed information determined by the designed model. Next to this evaluation of the model, recommendations were made for implementation of the model into the organization. These recommendations are based on the fit with the currently running decision-making process.

Based on the evaluation of the model with the case, recommendations are formulated for improving the designed model further in order to fully comply with the needs of the Business Incubator.

Results

The current decision-making process

At the Business Incubator, two processes are identified that operate in parallel: the Bell-Mason approach and the Project Management Process (PMP) approach. The Bell-Mason approach is based on ‘venture thinking’, meaning that its principles lie in starting a corporate venture. Within the DSM Innovation Center, ventures are started based on discontinuous innovation projects that were assessed as having platform potential. This approach is advantageous in the sense that it stimulates venture thinking in executing innovation projects, which is based on different deliverables than standard new product development processes. Bell-Mason is not officially integrated into the ‘best practices’ within the Business Incubator. The PMP approach is a standardized procedure within the entire organization for managing all projects. It is a stage-gate approach with clarified deliverables at the end of each stage. However, the Feasibility phase of the PMP approach lacks structure, leading to scattered activities and projects that are poorly positioned into the process.

The main characteristics of the decision-making process on an organizational level were identified. First of all, decision-making is said to be rational, while the reality is that intuition and ‘gut feeling’ of the decision-makers mostly influence the decisions that are taken. Second, different roles were identified of the stakeholders involved in the decision-making process. A distinction was made between decision-makers, the supporting stakeholders, the stakeholders that need to provide an approval of the decision and the stakeholders that need to be consulted or notified of the decision. High-level management is usually the decision-maker, but is mostly involved at the end of the fuzzy front end. Third, the level of detail on which decisions are based increases when moving through the fuzzy front end model, meaning that more and more specific information is needed in every subsequent phase.

The structured fuzzy front end model

Based on the models found in literature and the current decision-making process, the structured fuzzy front end model was designed (Figure 1). The phases are distinguished as follows:

- Pre-phase zero considers an initial screening of an opportunity after an idea has been generated from the preceding idea generation phase. The deliverable from this phase is a five-to-ten pager on the innovation. The decision to move forward is recommended to be taken by the project owner.
- Phase zero: the innovation is positioned into the relevant market segments, which means that in-depth technological and market information is needed. The deliverable of this phase was recommended to be a concept for the development strategy of the product. The project owner is again recommended to make the decision to move forward, after getting the approval from a high-level manager involved in the project.
- Phase one: the final phase of the fuzzy front end considers developing a business case for the innovation project. The business case serves as a deliverable for this phase, which means that the activities undertaken are recommended to focus on the financial specifications of the project, planning its development, planning for different scenarios that may occur and mapping the value chain in order to identify development partners, suppliers and distributors. The ultimate decision to move forward is made by the venture

steering group, which entails the high-level management that assesses the platform potential of a project.

Allocation of assessment factors

For each phase of the designed model (Figure 1), assessment factors were allocated through the panel study. One key observation during this study was the average scoring given to each factor: the average scores showed large error bars, indicating that the 15 panel members did not agree on the importance of the factors. This observation led to separating the selected assessment factors based on two aspects: 1) the degree of disruptiveness of the projects that the panel members were involved in, and 2) the position the panel members took in the organization.

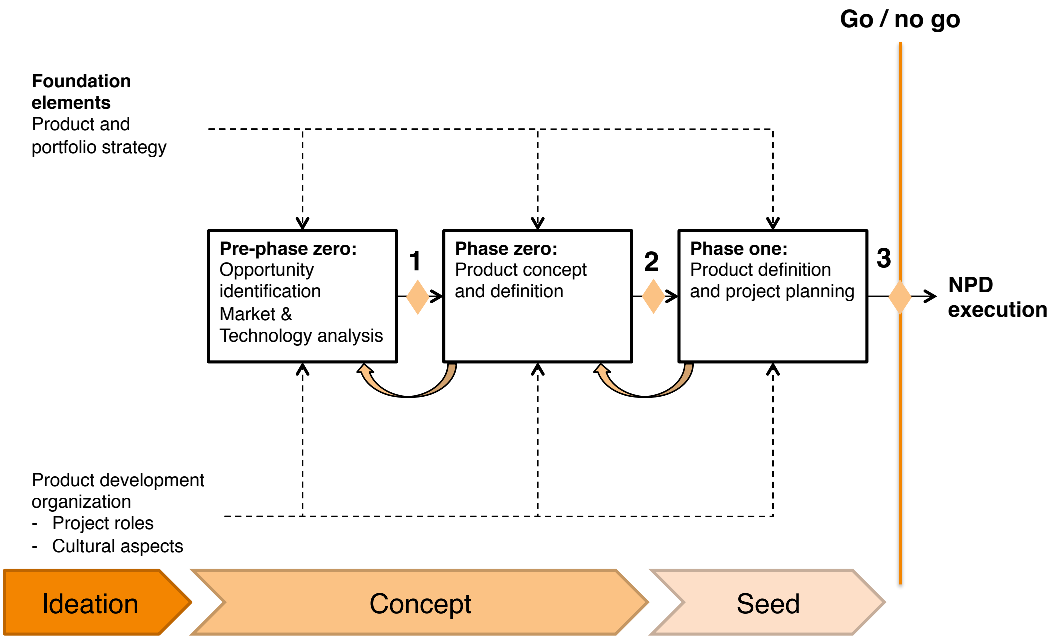

Figure 1. The structured fuzzy front end model.

Neither of the distinctions have yielded the exact source of the disagreement between the panel members, which emphasized that the types of information needed for a successful fuzzy front end strongly depends on the views and opinions of the individual. Therefore, intuition and gut feeling are concluded to be inherent to the fuzzy front end process and cannot be completely replaced by rationality.

Recommendations for implementation

The structured fuzzy front end model was recommended to be implemented in the Feasibility phase of the PMP approach currently used within the organization. The start and end of the designed model perfectly fits into this phase, along with the deliverable set when finishing this phase (i.e. business case). By implementing the fuzzy front end model into this phase, several advantages are gained. First, the model stimulates a more structured way of thinking than was the case before. The Feasibility phase is now divided into multiple steps, which each have the possibility of moving to a previous step if not enough information is collected. Second, the model provides a more focused set of activities due to the definition of the assessment factors in each phase. Third, the decision-making inherent to the process is more substantiated, meaning that more rationality is implemented into the model.

An important point of attention considering the implementation of the model is that the flexibility needed in discontinuous innovation projects may be reduced by the definition of stages and gates in the fuzzy front end. Therefore, a trade-off exists in maintaining flexibility versus the reduction of uncertainties. Moreover, the lack of consensus on the assessment factors allocated to each phase needs more attention.

Lessons from the case application

After positioning the case into the designed model and performing the feasibility study with the methodology prescribed by the assessment factors for the relevant phase, the model performed well in the sense that the assessment factors allow for a detailed, but yet generalizing a visualization of scores. Moreover, the predetermined list of assessment factors allowed the identification of knowledge that was already present inside the organization considering the project at hand. Most importantly, it provided insight into the knowledge that still needed to be gathered.

Despite of the clear advantages of the model, missing elements of the model were identified. First of all, the model did not provide a clear strategy recommendation in terms of moving into the market as a first mover or as an early follower. Both scenarios provide distinct advantages, which are not taken into account by the model. On the other hand, this also provides a degree of flexibility to the model, as the executer can build his or her own business plan based on a strategy in that respect. Second, the weighting of factors could not be determined due to the lack of consensus in the panel members, which implicated that the scoring of each assessment factor may not be reliable, as some factors can be more important than others. My recommendation is to obtain insights from external experts for each project in order to determine weighting for each project separately, as each discontinuous innovation project considers different requirements. Finally, the model made no distinction between niche applications or large-scale applications, which both required different strategies for development. As was the case for the first-mover versus early follower debate, this strategy is recommended to be undertaken by the project executer.

Evaluation of the model based on the set requirements

The model's functionality was assessed on the requirements that were set at the beginning of the study. First, the uncertainty in both market and technological aspects was reduced by the fact that assessment factors from both categories were allocated to each phase of the model. In that sense, the model complied with this requirement. However, the reduction of uncertainty can be counteracted by a subjective scoring of these assessment factors, as intuition and gut feeling still played an important role in the factor allocation study.

Second, all activities within the model were aligned with an overall strategy that needs to be present before the innovation project is undertaken. Moreover, the assessment factors that consider strategic aspects, such as *strategic fit* were indicated to be important for assessment studies. In conclusion, the requirement of strategy alignment was accounted for.

Third, the decision-making roles within the DSM Innovation Center were allocated to the phases of the model. By doing so, the executers of the projects have a clear view on the process they need to move through. Furthermore, the model was easy to use for both executer and decision-maker, as it provides both a detailed and general view of the information gathered.

In terms of applicability of the model in DSM, the alignment of activities and final deliverables make the model suitable for use as part of the PMP approach. This implicates that no significantly large changes need to be made to the current organization. Moreover, the model realized an integration of both the Bell Mason approach and the PMP approach, which was indicated to be important through the interviews conducted earlier.

Conclusion

The results in this thesis have shown that it was possible to structure the fuzzy front end in such a way, that activities and types of information needed could be represented, while also implementing current decision-making roles. The method presented for structuring the fuzzy front end has proven itself useful to determine the types of information and activities that need to be undertaken. Other organizations could learn from this method and apply it in their own environments. This model is not generalizable to other organizations, as it contained specific DSM cultural aspects. These aspects were as follows:

- The integration of the Bell Mason approach and PMP approach;
- The decision-making roles during the fuzzy front end

Considering the generalizability, several points should be taken into account. The model was tested in one phase and with one particular case. This implicates that the performance of the model is yet to be tested in other phases and with projects of a different nature. Moreover, the weighting of the assessment factors has not been determined, which could result in different outcomes from assessment studies compared to not applying weighting. Thus, when applying this model to other projects, it is recommended to get a good grasp of the project at hand before entering the fuzzy front end: this would clarify the relevant activities and assessment factors.

Recommendations for future research

Further research in this field should be targeted at other organizations that deal with discontinuous innovations on a regular basis. This would entail including companies into the study that could have a department similar to the Business Incubator. This procedure would provide more insights into the similarities across industries in this sense and the degree to which the designed model is generalizable in its phases and assessment factors. Moreover, more research is recommended on the panel study performed in this project. The lack of consensus should be investigated further, as a consensus on the assessment factors is important for a successful and consistent fuzzy front end across different business groups. It is recommended to perform the panel study with a true Delphi panel, meaning that the panel members should be able to discuss the results from each round. Also, the sample size of the panel posed challenges, as the amount of employees involved in discontinuous innovations is scarce within DSM. Including other companies in such studies would solve this problem.

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1. INTRODUCTION

The commercial success of new products is the ultimate goal and benchmark of new product development within companies. In order to obtain this success, many steps need to be taken before a new product may be brought into the market. This process consumes time and resources and encompasses many uncertainties. Successful innovation is the key for commercial success, which is largely determined by successful completion of the fuzzy front end of new product development (Reid & de Brentani, 2004). Smith and Reinertsen were the first to popularize the term *'fuzzy front end'* (Smith & Reinertsen, 1991), which can be defined as the earliest phase of new product development, starting with the presence of an idea and leading up to the actual development of the idea or its termination (Murphy & Kumar, 1997). This phase is intrinsically marked by uncertainties, in particular for disruptive (or 'new-to-the-world') innovations (Herstatt, Verworn, & Nagahira, 2004).

The source of these uncertainties is found partially in the focus taken by science and business scientists, who have proposed theoretical models for the fuzzy front end that aim for quantifiable outcomes. For disruptive innovations quantifiable outcomes are difficult to come by, as both market and product can be completely new. A general description of activities does not suffice to reduce the uncertainty that is inherent to disruptive innovation and to structure the discussions considering the feasibility of these innovations. DSM, a Dutch life science and material science multinational, also recognized this problem. Currently, the selection process of disruptive ideas and the further assessment of their feasibility are questioned within DSM, as no consensus or 'best practice' exists on the approach to be used. Also, activities within this process tend to be scattered, leading to a lack of a foundation on which decision-making is based considering the new technologies. As a result, ideas are assessed as economically viable, while later on in the development process information surfaces that undermines this conclusion. This situation inspired DSM for the research topic discussed in this thesis: how can the screening of ideas and their feasibility assessments be structured in such a way that uncertainties in further development are minimalized? What information is needed to proceed to the next step and to assess whether the idea is truly economically viable? This research will be executed at the Business Incubator of the DSM Innovation Center, which

This thesis builds upon previous models that have been developed in order to indicate which assessment activities and assessment factors are important to consider in each phase of the fuzzy front end. The term *'model'* is defined as a theoretical model, which shows different phases of a process, i.e. the fuzzy front end of new product development. The objective of this research consists of multiple sub-goals, which are:

- Design a model to structure the fuzzy front end of new product development based on literature and insights from experts within DSM;
- Provide insight into the relative importance of assessment factors within each phase of the model, which will indicate which activities to undertake in each phase. This will also determine the contents of the deliverables at the end of each phase;

- Gain understanding in the roles of the people involved in the decision-making process within the fuzzy front end, as each phase holds different responsibilities for each involved employee.

The structured model will be tested by a currently running case at DSM in order to determine whether the model provides the necessary information for decision-making. The case considers a feasibility study in order to determine the key success factors and assumptions under which a new compound can be economically viable as a platform. The deliverable at the end of this research is therefore twofold: on one hand, a structured model of the fuzzy front end is delivered, while on the other hand a recommendation will be given to DSM on the strategy to further develop the new compounds.

2. RESEARCH PRELIMINARIES

Structuring the fuzzy front end of new product development has proven to be not straightforward and far from easy. The daunting character of this task is caused by several knowledge gaps in both new product development literature and the internal organization of the company. This section will present the problem statement based on these gaps, as well as the research questions and approach with which the gaps are expected to be filled. Finally, the relevance of this research for literature and the company is discussed.

2.1 PROBLEM STATEMENT

2.1.1. ATTEMPTS AT STRUCTURING THE FUZZY FRONT END

A general view of the fuzzy front end in relation to new product development is based on the notion that the fuzzy front end entails the generation of ideas for new product development, after which one idea is further developed during the development phase (Figure 2) (Cooper, 1990; Murphy & Kumar, 1997). The fuzzy frond end may be depicted as a funnel, as the number of ideas is reduced while moving through the funnel (Wheelwright & Clark, 1992). The reduction of ideas is based on (initial) feasibility assessments on the economic viability of the ideas, while the idea proposals become more focused and detailed. The development phase consists of further focus-narrowing steps, which ultimately result into the commercialization and market introduction of an economically viable new product. When taking a closer look at the fuzzy front end, the process starts with the identification of an opportunity that presents itself in the market or elsewhere. After the opportunity has been identified, the generation of ideas in order to target this opportunity is started. This yields several ideas that are subsequently assessed on their feasibility to further develop as new products.

As indicated in the Introduction, many scholars within new product development literature have agreed that the 'fuzziness' poses great challenges for companies to manage the fuzzy frond end, as it is often ill-defined and most decisions are made ad hoc (Montoya-Weiss & O'Driscoll, 2000). The front-end phase is especially important in high-technology industries (Carbone, Sherman, & Tippett, 2012) such as the biotechnology industry. High R&D expenditures, long time spans in product development and short market windows are inherent to these industries, which makes new product development utterly challenging. In order to tackle these challenges, a wide variety of models were designed in order to structure the fuzzy front end. These models range from stage-gate models (Cooper, 1990; McGrath, 1996) to circular models (Koen et al., 2001).

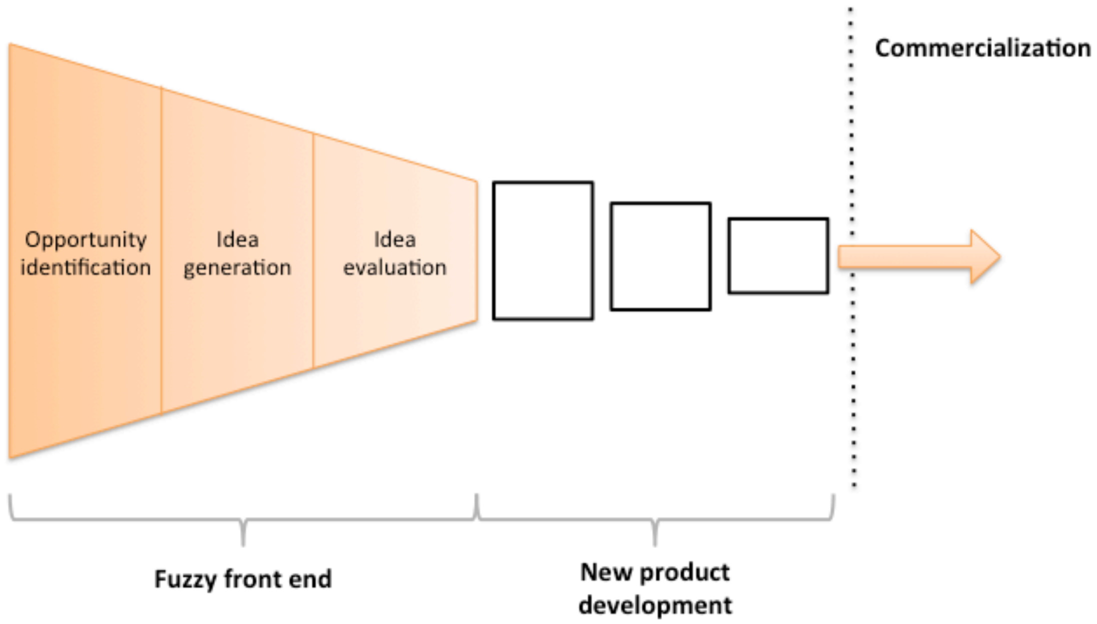

Figure 2. A schematic representation of the fuzzy front end of innovation and new product development.

The concept that these models have in common is that these models are mostly based on incremental innovations that proceed through the fuzzy front end funnel. Incremental innovations are by definition less risky than disruptive innovations due to significantly smaller uncertainties that are involved in the process. Moreover, the source of opportunities or ideas is different for incremental innovations compared to disruptive innovations (Reid & de Brentani, 2004). Within the Business Incubator of the DSM Innovation Center the focus lies on generating ideas or product platforms revolving around disruptive innovations that could meet (future) market needs. As many uncertainties are involved in disruptive projects, a structured model is needed to move through the fuzzy front end while minimizing the uncertainties for new product development.

Moreover, the wide range of models developed for the fuzzy front end indicates that no consensus exists on a best practice within managing this phase. Within the DSM Innovation Center attempts are made to identify best practices in innovation management, with the intention to implement these practices in the company. The structuring of the fuzzy front end still has not been accomplished in a way that fits the activities undertaken in the Business Incubator. This emphasizes the need for a model that is complementary to the disruptive nature of the projects undertaken in this department.

Another identified gap is found when considering the decision-making process involved in the fuzzy front end. Scholars have merely identified the steps that need to be taken in order to successfully move through this phase, but have not paid attention to the organizational structure around the model (Cooper & Kleinschmidt, 1997; Khurana & Rosenthal, 1997; Reid & de Brentani, 2004). In order to move from one step to the next, decisions need to be made, which raises the question who are involved in this decision-making process and in to what extent or in which roles. The structured model for the fuzzy front end needs this division of roles in order to conclude whether the model is suitable for implementation into the organization.

Therefore, the main problem that is investigated in this thesis is on the structuring of the fuzzy front end in order to ensure a successful new product development, based on the challenges of managing disruptive innovations and the organizational decision-making roles involved.

2.1.2. ASSESSMENT FACTORS IN A STRUCTURED FUZZY FRONT END MODEL

The outcome of the fuzzy front end is of great influence on the success or failure of new product development (Carbone et al., 2012; Cooper & Kleinschmidt, 1997; Cooper, 1999; Verworn, Herstatt, & Nagahira, 2007; Zhang & Doll, 2001). The fuzzy front end serves as a screening phase of ideas, where many types of information are gathered in order to make key assumptions on the product. This information is crucial in predicting the feasibility of the new product in terms of economic viability. Extensive research has been conducted into the factors that make new product development successful, but less attention was paid to the required factors for a successful fuzzy front end outcome. Though Carbone et al. have succeeded in listing the types of information or assessment factors needed during the fuzzy front end (Carbone et al., 2012), they have not researched in which phase(s) of the fuzzy front end these factors apply. As the uncertainty decreases when moving through the fuzzy front end funnel, the focus on a product becomes narrower, indicating that the level of detail is larger. This is reason to believe that each phase of the fuzzy front end has different information requirements on which to decide whether to move to the next phase.

The Business Incubator not only needs a structured approach to move through the fuzzy front end, but also needs an indication into the activities that need to be undertaken in each phase of the model. These activities are closely linked to the type of information that is needed in these phases. Therefore, this thesis will provide a structured fuzzy front end model, while providing more detail into the assessment factors that are most important in each phase of this model.

2.2 RESEARCH STRUCTURE

Summarizing section 2.1, a structured fuzzy front end model is needed, which provides a means to reduce uncertainty in disruptive innovation decisions within the Business Incubator at the DSM Innovation Center. The structuring of this model is achieved by defining separate phases within the fuzzy front end, along with information collection activities in each phase. These activities are determined by listing assessment factors for each phase. In this thesis, these factors are defined as types of information or information sources needed for assessing the potential of a disruptive innovation. The yielded model was tested using a currently running case at the Business Incubator, which revolves around the feasibility of further development of a group of new compounds.

In order to ultimately obtain a valid structured fuzzy front end model, the research activities undertaken in this thesis were divided into four phases (Figure 3). The first phase entailed a thorough analysis of the problem at hand, by identifying the problem for both DSM and the scientific community. This phase has already been conducted and presented in section 2.1. As the problem statement has yielded the conclusion that the fuzzy front end at the DSM Innovation Center is in need of a structured model, a set of requirements to this model is needed. The second phase entailed setting up the list of requirements by means of a literature study on current models and interviewing internal experts within the DSM Innovation Center.

During the second phase of this research, a set of requirements for the structured fuzzy front end model was formulated. This set was used as the input for the third phase, which focused on the actual structuring of the fuzzy front end model. Taking the following steps achieved the structuring of the fuzzy front end:

1. The literature study on current models was used in order to list the characteristics of these models and compare these in terms of fit to the requirements stated in phase 2. The most appropriate models were used as a basis for proposing a structured fuzzy front end model.
2. Expert interviews were conducted in order to gain insight into the current decision-making process within the fuzzy front end. The yielded decision-making characteristics were fitted into the model.
3. The proposed fuzzy front end model was extended through the allocation of assessment factors to each phase of the model by means of a panel study with innovation experts within DSM. Also, the importance of these factors was assessed for each phase of the proposed model.

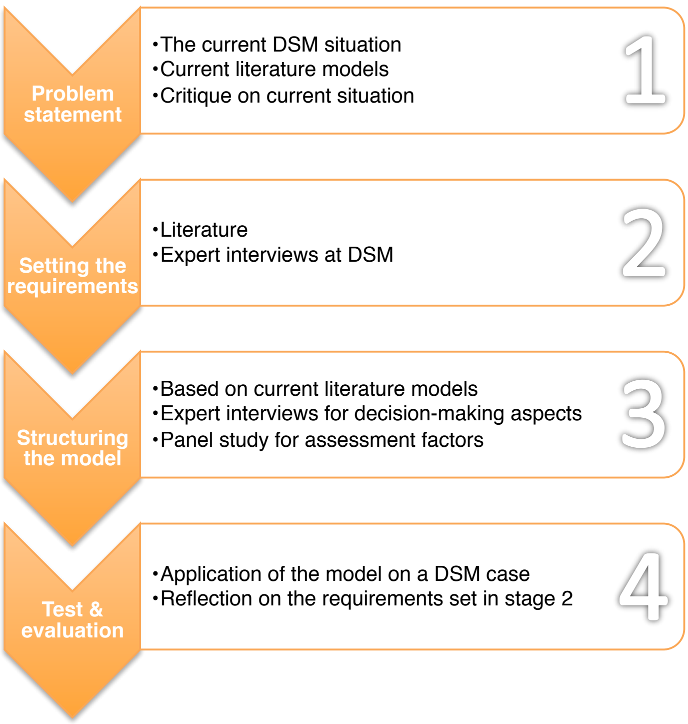

Figure 3. A schematic representation of the phases in which the presented research is executed.

The fourth and final phase of this research involved the validation of the proposed model. This phase decided whether the proposed fuzzy front end model produced sufficient material for a feasibility assessment of a currently running case at DSM. This case was positioned into the proposed model and the assessment activities of that phase were executed. Moreover, this phase served as a reflection on the compliance of the proposed model to the requirements set in phase 2.

2.3 RESEARCH QUESTIONS

In order to support the execution of the phases presented in section 2.2, research questions are formulated. The main research question is formulated as:

"In what way can the fuzzy front end for disruptive biotechnological innovations be structured while highlighting the relative importance of assessment factors for each phase?"

The answer for the main research question is supported by the following set of sub-questions:

1. Which models are currently proposed for the fuzzy front end?
2. What requirements are important to consider in structuring the fuzzy front end?
3. How is the current decision-making process in the fuzzy front end organized for disruptive innovations at DSM?
4. What assessment factors are important for each phase of the fuzzy front end at DSM?
5. To what extent can DSM learn from the structured fuzzy front end and the assessment factors in each phase?
6. What are the recommendations for other organizations in structuring the fuzzy front end?

The sub-questions are involved in different phases of this thesis research. The way in which these relate to the different phases and to each other is presented in Figure 4.

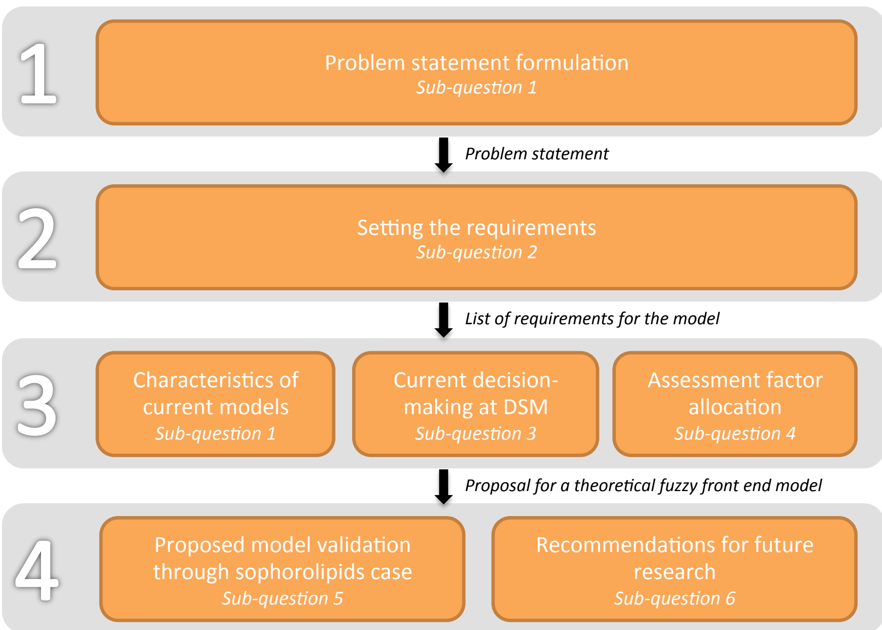

Figure 4. The sub-questions in relation to the four research phases.

The phases and corresponding sub-questions are discussed in different chapters throughout this thesis. The chapter outline, including corresponding sub-questions, is presented in Table 1.

Table 1. The chapter outline in this thesis.

Chapter	Answers	Content	Yield
2	Sub-question 1	• Problem exploration • Based on flaws of current models	Problem statement
3	Sub-question 1 and 2	Theoretical background based on literature, containing: • Types of uncertainties • Current fuzzy front end models • Assessment factors for the fuzzy front end	Requirements for the model based on literature
4	Sub-question 3	The current decision-making process within DSM is presented based on expert interviews.	Decision-making characteristics at DSM
5	Sub-question 4	A proposal for a fuzzy front end model is assembled based on the findings from sub-questions 1, 2 and 3. The assessment factors found in chapter 3 are positioned into this model through a panel study.	A complete model proposal with decision-making activities and assessment factors, including implementation into the organization.
6	Sub-question 5	The DSM case is used as a test and validation tool of the model.	Evaluation of the model based on case results
7	Sub-question 6	Recommendations for future research based on the evaluation of the model in Chapter 5 and the reflection on the requirements set in Chapter 3.	Recommendations in terms of future research proposals

2.4 APPROACH AND DATA GATHERING METHODS

In order to answer each sub-question, the following methodology will be used per question:

1. **Which models are currently proposed for the fuzzy front end?**

   Literature study
   For insights into the models proposed until now, a literature study will be performed. These models provide a structured way in proceeding through the fuzzy front end of new product development. The main goal of the literature study is to provide an overview of these models and describe their features. This overview will be the basis for structuring the fuzzy front end at DSM.

2. **What assessment factors are important in order to successfully proceed through the fuzzy front end?**

   Literature study
   In literature, success factors are described on a project level that indicate the type of information and activities needed to successfully move through the fuzzy front end, thereby minimizing the uncertainties along the way. The goal of the literature study is to list the factors that are important for the fuzzy front end. This list of factors forms a starting point for assessing their relative importance later on.

3. **How is the current decision-making process in the fuzzy front end organized for disruptive innovations at DSM?**

   Interviews with internal experts at DSM involved in disruptive innovation decision-making
   In order to obtain insight into the way the fuzzy front end is currently structured at DSM and on what basis decisions are made during this phase, interviews will be held with 7 internal experts who are closely involved in these processes. These interviews will provide an understanding of the organizational structure around disruptive innovation management at DSM, as well as the activities and desired deliverables within the fuzzy front end. Moreover, the assessment factors identified in sub-question 2 can be confirmed on their importance.

4. **What assessment factors are important for each phase of the fuzzy front end at DSM?**

   Panel study with internal experts
   By using a panel, a qualitative overview is obtained of the importance of the assessment factors (and therefore, activities) in each phase of the structured fuzzy frond end model. To this end, a panel is used of 10 to 15 internal experts, who have similar backgrounds and experience in disruptive innovation processes. This panel size will obtain valid results, given that the conditions on the background are met (Delbecq, Ven, & Gustafson, 1975). The Delphi Technique is based on multiple rounds, where the panel is asked to anonymously provide answers to a (short) questionnaire. The results from each round are gathered and serve as input for the subsequent round. The number of rounds will be equal to the number of stages of the structured fuzzy front end model. The panel will be asked to indicate for each phase which assessment factors are important in that particular phase and which of these factors is least or most important. By doing so, for each phase a list of assessment factors will be obtained.

5. **To what extent can DSM learn from the structured fuzzy front end and the assessment factors in each phase?**

   Analysis of the model and obtained results
   The current decision-making process, the proposed structured model as derived from literature and the results for the assessment factors will be analyzed in order to obtain a complete picture for the recommended fuzzy front end procedure for DSM. From this analysis, a recommendation will be given to DSM in order to improve its methodology to deal with the fuzzy front end.

   Case application
   Applying the currently running case on the model will test the results obtained on the structured model for the fuzzy front end. This case is a feasibility study on the market and technological potential of these compounds. By running this test, the applicability and usability of the model for DSM is analyzed and a recommendation can be given on the implementation.

6. What are the recommendations for other organizations in structuring the fuzzy front end?

   Reflection

   The relevance of the findings on the structured fuzzy front end model will be reflected upon considering its generalizability to other biotechnological companies. This part of the research will indicate if the results may be extrapolated to the biotechnological industry in general. Also, the effect of the organizational culture will be reflected upon in order to come to this recommendation.

2.5 RESEARCH RELEVANCE

The relevance of this research is divided in two perspectives, which are 1) the relevance from a scientific perspective, and 2) the relevance from the perspective of DSM. The scientific relevance of the presented research is that insight is gained into the types of information needed for each phase of the fuzzy front end in order to make decision-making more effective and efficient. Most literature focuses on general success factors of the fuzzy front end, but fail to present an in-depth analysis of their relevance to each phase. This research will move the factors from a project level to a phase level, where characteristics of specific projects are taken into account Moreover, insight will be gained into the implications of organizational culture and structure when implementing such a model. These findings may be used in other high-technology companies in terms of drawing lessons out of the organization structure around the fuzzy front end and factors that need to be accounted for during each phase.

The relevance for DSM is that insight is gained into managing the fuzzy front end for disruptive innovations within the Business Incubator, taking into account set targets and objectives. Moreover, practical information is provided on which assessment activity to undertake in each stage of the fuzzy front end, along with set deliverables.

3. THEORETICAL FRAMEWORK

3.1 UNCERTAINTIES IN BIOTECHNOLOGY MARKETS

The biotechnology industry can be classified as a high-technology industry, which results in similar characteristics considering the marketplace. However, the biotechnology market shows features that are not generalizable for other high-technology markets. This section will list the general characteristics of high-technology markets, after which similarities and differences with the biotechnology market will be discussed. Finally, the impact of these market characteristics on the types of innovations will be evaluated.

3.1.1. UNCERTAINTIES IN HIGH-TECHNOLOGY MARKETS

High-technology may be defined as advanced technology, which is a concept that changes over time (Mohr, Sengupta, & Slater, 2009). Many industries are considered as high-technology industries, e.g. electronics, information technology, nanotechnology and pharmaceuticals. Mohr has identified three characteristics or features that these industries have in common and are not shared by non-high-technology industries. These features are:

1. Market uncertainty
2. Technological uncertainty
3. Competitive volatility

MARKET UNCERTAINTY

According to Moriarty and Kosnik, market uncertainty is one of the pillars that distinguishes high-technology market from low-technology markets (Moriarty & Kosnik, 1989). This uncertainty originates from the lack of knowledge of customer needs and the market's structure, size and dynamics. Especially a breakthrough or discontinuous innovation is associated with an inherent high market uncertainty, as customers have little to no experience with using the product or technology (MacCormack & Verganti, 2003). The size of the addressable market and customer's needs are difficult to estimate in that case. Moreover, the speed of adoption of the product is hardly predictable (Mohr et al., 2009). MacCormack & Verganti have identified factors that contribute to the uncertainty considering the marketplace (MacCormack & Verganti, 2003), which are:

- Lack of knowledge of the product from the customer's perspective;
- No general definition or understanding of the targeted market segments among experts;
- The ambiguous nature of the scale on which market assessments are performed.

Apart from the market uncertainty, the uncertainty considering the technology or product should also be considered. The next section will elaborate on this type of uncertainty.

Technological uncertainty

The second characteristic of high-technology markets, as identified by Mohr, is the uncertainty regarding the performance of the technology (Mohr et al., 2009). The main source of this uncertainty is the question whether the technology delivers on the desired performance for the customer. However, other aspects feeding technological uncertainty include the required development time of the technology, unintended consequences (Mohr et al., 2009) and the threat of obsolescence (Rajamäki, 2008). Even though these factors are determined as sources of technological uncertainty, additional technology- or industry-specific sources are important to consider. For instance, the pharmaceutical industry deals with different types of technological uncertainties (e.g. the way the human body responds to drugs) than the software industry (e.g. the degree to which operating systems support the developed software).

An important aspect to consider in technological uncertainty is the difference in the preferences of clients versus end-users. Specifically, in business-to-business (B2B) settings, the desired performance or requirements of the technology or product may differ between clients and end-users (Belliveau, Griffin, & Somemeyer, 2004). For example, the requirements of additives for cosmetic products are different for cosmetic formulators than the consumers using the cosmetics. Cosmetic formulators may consider low price, ease of application in their formulations and high formulation functionality as important, while the end-user most likely considers the advertised functionality of the whole cosmetic product and its appearance. Therefore, the exact definition of technological uncertainty and its sources depend on the setting in which the firm operates.

Competitive volatility

Market and technological uncertainty have been named as the two major characteristics of high-technology markets, though Mohr has identified a third characteristic: competitive volatility (Mohr et al., 2009). This characteristic is described as the degree to which the competitive environment changes in terms of number/type of competitors and their strategies. Competitive volatility is argued to be part of market uncertainty, though Mohr discusses these characteristics to be quite different, as market uncertainty mainly concerns clients/end-users. The uncertainty considering the firm's competition is mainly important when discontinuous innovations are considered, as the firm cannot know if competitors will enter the same field and the strategy that will be deployed (Mohr et al., 2009).

Other characteristics

The uncertainties related to the market, technological performance and the competition characterize the high-technology industry, though others aspects determine this industry's character as well. John et al. have identified other characteristics that are not directly related to uncertainties, but contribute to the complicated nature of high-technology industries (John, Weiss, & Dutta, 1999). These aspects are:

- Unit-one costs: producing one unit of a product is associated with high costs, while these costs decrease once more of the same product is produced. This is also referred to as economies of scale (Srinivasan, 2008).

- **Tradability problems:** tacit knowledge or know-how is difficult to value, which complicates selling this knowledge to other parties, e.g. through intellectual property (John et al., 1999).
- **Knowledge spillovers:** the exchange of knowledge between parties involved in the same field accelerates the build-up of knowledge, compared to the speed of knowledge expansion when one party executes product development on its own. These knowledge spillovers are widely observed in high-technology industries, as the nature of the knowledge involved in these industries is highly specific and takes on tacit forms (John et al., 1999; Schilling, 2012).
- **Network externalities:** as adoption of the product increases, its value increases as well. These externalities are either direct or indirect. Direct network externalities consider the value increase of the product to the user as adoption increases (e.g. the value of Facebook relies on its number of adopters). Indirect externalities take into account the increase of the product's value as complementary products are developed by other parties, which is directly linked to the number of adopters of the product (John et al., 1999; Mohr et al., 2009; Schilling, 2012).

High-technology industries are complex due to the uncertainties that are involved, especially in discontinuous innovations, while the value of the high-technology product depends on factors such as the number of adopters, the production scale and the degree to which the knowledge involved can be valued and transferred. Therefore, these industries undergo complex (inter)organizational processes that need to be taken into account when commercializing a discontinuous product. As was stated previously, the biotechnology industry is considered to be a high-technology industry. The next section will elaborate on the similarities and differences of the characteristics stated in this section with the characteristics of the biotechnology market.

3.1.2. BIOTECHNOLOGY MARKET VERSUS HIGH-TECHNOLOGY MARKET

As the biotechnology industry can be considered as a high-technology industry, similarities in its characteristics can be observed. Rajamäki discussed the characteristics of the pharmaceutical biotechnology market in terms of market uncertainty and technological uncertainty, after which conclusions were drawn on the challenges biotechnological firms need to deal with considering the market and technology (Rajamäki, 2008). Therefore, the biotechnology market shows characteristics similar to those of high-technology markets. However, it is also argued that the biotechnology market has a unique market structure with special needs. McMurray and Jones stated that the biotechnology market is defined by two parameters that are not considered in general high-technology markets. First, the innovative behavior of the market is crucial in order to gain insight into the diffusion of a discontinuous technology into the marketplace. Second, decision-leadership in the market plays an important role in the speed of diffusion: all biotechnology firms entering the market with a new technology are seen as the first movers, meaning that they have a decision-leadership position compared to followers (McMurray & Jones, 2003). This argument was raised in 2003, up until which time the focus within biotechnology was mainly on molecular cell biology and biopharmaceuticals, leading to emerging technologies such as recombinant DNA techniques and genome sequencing. The contemporary focus of biotechnology has expanded, moving into an industrial character due to the use of microorganisms in the production of bio-based chemicals. However, biotechnology is still discussed in terms of biopharmaceutical drug discovery in literature, which is merely a type of biotechnology market rather than the overall biotechnology market in itself.

The second half of the 2000s shows that white biotechnology, as industrial biotechnology is referred to, experiences growth in terms of scientific publications, meaning that before that time, little attention was paid to this type of biotechnology. This type of biotechnology is named as the enabling technology for the chemical industry (Hatti-Kaul, Törnvall, Gustafsson, & Börjesson, 2007) and is even referred to as a paradigm-shift from petrochemical production methods towards a bio-based approach (Lorenz & Zinke, 2005). When taking into account the specific characteristics of the white biotechnology industry, one encounters many similarities with the chemical industry, which is a high-technology industry. It competes in the same area, as the produced chemicals serve as a sustainable and environmentally friendly substitute for existing (petro)chemicals.

In conclusion, the characteristics of the contemporary biotechnology market in terms of bio-based production of chemicals, which is the scope of this thesis, are highly similar to the characteristics of the general high-technology market. As the characteristics stated by McMurray and Jones to be biotechnology-specific are more related to medical biotechnology than industrial biotechnology, these need to be revised for the latter.

3.1.3. Projecting uncertainties on types of innovations

The uncertainties involved in high technology may be projected on the types of innovations that exist. In this case, two types of innovation will be considered: incremental and discontinuous innovations. Incremental innovations are considered to be (small) improvements to existing products, thereby not changing the product itself significantly (Schilling, 2012). On the other hand, discontinuous innovations are characterized by their disruptive nature (Abernathy & Clark, 1985; Schilling, 2012), meaning that these innovations generally consider an entirely new concept that is not yet known. Herstatt et al. indicated that there are several degrees of disruptiveness: a product may be completely based on both a new technology and a new market, but it can also be disruptive in one of those areas instead of both. According to these authors, a product that is new to market but is not new from a technological perspective is considered as a market innovation, while the opposite is called a technological innovation. Both are disruptive in the sense that it is completely new to either market or technology (Herstatt et al., 2004).

Lynn and Akgun have discussed that the two types of innovations are linked to the uncertainties that are characteristic for high-technology markets. These authors concluded that the degree of disruptiveness is correlated with both market and technological uncertainty (as discussed in section 3.1.1.): the higher the degree of disruption, the more uncertainties are involved (Lynn & Akgun, 1998). Combining the degree of disruptiveness and the uncertainties involved, a classification of innovations based on degree of uncertainty can be made (Figure 5).

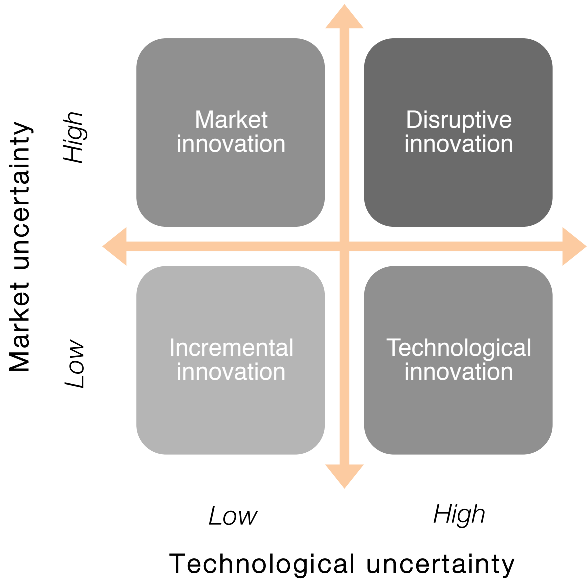

Figure 5. Types of innovation linked to the degree of uncertainties in high-tech industries. Adapted from (Herstatt et al., 2004).

As incremental innovations entail small changes to existing products in existing markets, the uncertainty regarding both market and technology is low. These innovation projects are therefore least risky compared to the others. Disruptive innovations are characterized by the opposite: due to high uncertainty in market and technology, the risk of such innovation projects is high. If a disruptive innovation is made in terms of technology in an existing market (technological innovation) the risk is not as high. The same holds for market innovations, when a new market is addressed with an existing technology.

3.1.4. Impact of uncertainties on business

Under conditions of uncertainty, especially in discontinuous innovations, the formulation of the strategy to undertake within a business becomes difficult (Crossan, Lane, & White, 1999; Frishammar, Floren, & Wincent, 2011). The procedure for decision-making within businesses is the main aspect that is impacted by varying levels of uncertainty. Courtney et al. have argued that underestimating the level of uncertainty leads to strategies that do not avert threats adequately, or do not take full advantage of the opportunities at hand (Courtney, Kirkland, & Viguerie, 1997). Moreover, uncertainties are significantly reduced if the appropriate analyses are performed, such as analyses of market trends in the case of market uncertainty. Even if these analyses do not provide a clear answer, it is still knowable to a certain extent. To which extent the information is knowable is determined by defining four levels of uncertainty in outcomes for businesses, which each have a different impact (Courtney et al., 1997):

1. Level 1: “A clear-enough future”:
   Managers merely need a single forecast in order to determine the strategy to undertake. This level has the least uncertainty.
2. Level 2: “Alternate futures”:

Managers have a few possible outcomes that are well defined, which can be analyzed through methods as option valuation models.

3. Level 3: "A range of futures":
   A range of possible scenarios or outcomes exists based on fixed key variables, but no discrete natural scenarios exist. This level of uncertainty is most common in companies in emerging technologies. Scenario planning is used as an analytical tool.
4. Level 4: "True ambiguity":
   Multiple sources of uncertainty (i.e. market and technology) interact, resulting in an environment that is impossible to predict or base forecasts upon.

Considering these four levels of uncertainty, level 4 uncertainties have the most impact on decision-making in businesses, as the decision-making process tends to be purely based on intuition due to the impossibility of forecasting. However, level 3 uncertainties have a fairly large impact as well. Even though a range of possibilities is identified, the output of each scenario is uncertain. Therefore, scenario planning and the preparation of risk mitigation strategies are of utmost importance for coping with the uncertainties in outcomes. The least uncertainties are involved in level 1 and level 2 situations, as information on the key parameters is readily available, given that the analyses are performed adequately.

Projecting the level of uncertainties on the types of innovations, one can conclude that level 4 uncertainties are related to disruptive innovations (Figure 5). As stated, both market and technological uncertainties are high in these innovations, which causes an interaction of multiple sources of uncertainties. Therefore, the impact on decision-making in business is highest with these type of innovations. It should be noted that this impact is not necessarily negative: level 4 uncertainties usually entail projects that are high-risk, but high-reward. If the decision-makers have a suitable approach in coping or even reducing these uncertainties for disruptive innovations, business is impacted in a highly positive way.

3.2 FUZZY FRONT END OF NEW PRODUCT DEVELOPMENT

The fuzzy front end is defined as the earliest stage of new product development (NPD), where time and activity is invested in one or multiple ideas, before team alignment takes place to execute the idea(s) (de Brentani & Reid, 2012). The efforts made during the fuzzy front end are mostly related to idea exploration and assessment, up until the decision is made to invest in developing the idea (Cooper, 1990; de Brentani & Reid, 2012; Khurana & Rosenthal, 1997; Smith & Reinertsen, 1991). This stage of NPD has attracted the attention of many academics and managers, as the fuzzy nature of this phase implicates uncertainty and no clear definition of activities that need to be undertaken. A distinction is made between activities associated with the early fuzzy front end and later phases of this stage. It is argued that in the early fuzzy front end, the structuring of the opportunity and its recognition are important (Leifer, 2000; Urban & Hauser, 1993), while others state that information collection (March, 1991) and the so-called "up-front homework" (Cooper, 1996) are the key activities. In later stages, concept development and idea generation become more important (Cooper, 1990; Urban & Hauser, 1993), as well as more detailed information collection (Crawford & DiBenedetto, 2003; Crawford, 1980). Moreover, initial funds may already be designated to the exploration of the idea (Cooper & Kleinschmidt, 1986; Cooper, 1990). This section will discuss the general characteristics of the fuzzy front end relating to these activities and elaborate on their implications on achieving successful new product development.

3.2.1 CHARACTERISTICS OF THE FUZZY FRONT END

As described above, the activities within the fuzzy front end may differ while moving from the early phase to a later phase. In spite of the difference in activities, still general characteristics can be derived that describe the fuzzy front end. Kim and Wilemon have listed general characteristics of the fuzzy front end phase in comparison with the actual development of a product (Table 2) (Kim & Wilemon, 2002b). These elements show that the stakes during the development phase of new product development are higher than observed during the fuzzy front end phase. For instance, the budgets assigned to each phase differ from being low in the fuzzy front end to being high during development. This implicates that when an idea is abandoned, the damage is relatively small if done during the fuzzy front end compared to the development phase. Furthermore, the fuzzy front end is less structured and defined than the development phase, which is caused by the different management styles and the broad focus of the fuzzy front end as opposed to the development phase. Moreover, the fuzzy front end requires qualitative information, which means that decisions during this phase are more based on intuition and 'gut feeling' than is the case during the development phase (de Brentani & Reid, 2012; Reid & de Brentani, 2004).

The fuzzy front end of product development may also be described from the perspective of uncertainty theory, which states that uncertainty is the key element that causes fuzziness (Zhang & Doll, 2001). Uncertainty means that probabilities are difficult to assign to outcomes, which implicates that the more data is available, the less uncertainty one will have. Three types of uncertainties are involved: market uncertainty, technological uncertainty and competitive uncertainty (Clark & Fujimoto, 1991), which are the main characteristics of high-technology markets (see section 3.1.1). While progressing through the fuzzy front end, these uncertainties are minimized, as more information is obtained when actively exploring an idea (Kim & Wilemon, 2002a).

3.2.2 THE EFFECT OF THE FUZZY FRONT END ON NEW PRODUCT DEVELOPMENT

The activities undertaken within the fuzzy front end have a large impact on the course of new product development: they may determine whether the development of a new product is successful or fails (Carbone et al., 2012; Carbone & Tippett, 2004; Verworn, Herstatt, & Nagahira, 2006; Zhang & Doll, 2001). Based on this knowledge, several scholars in NPD research have identified success factors that allow successful management of the fuzzy front end. These success factors may be divided in two main categories: factors that determine the success of the fuzzy front end and factors determining the success of new product development. Khurana and Rosenthal argued that this division of factors is crucial, as the two phases need different activities and different skills (Khurana & Rosenthal, 1998). The factors related to each category will be discussed below.

Table 2. Characteristics of the fuzzy front end versus the development phase. Adapted from (Kim & Wilemon, 2002b).

Factors	*Fuzzy front end phase*	*Development phase*
Idea definition	Fuzzy, room for change	Well-defined, ready for development
Type of information needed	Qualitative, estimates	Quantitative, precise
Phase output	Decision whether to develop the idea	A product
Focus	Broad, but barely detailed	Narrow, but highly detailed
Idea rejection	Easy	Difficult
Degree of formalization	Low	High
Involvement of personnel	Individuals or small project teams	Cross-functional development teams
Budget	None to small	Large dedicated budget
Management style	Unstructured, need for creativity, experimental	Systematic and structured
Damage if abandoned	Small	Large
CEO commitment	None to small	High

SUCCESS FACTORS FOR A SUCCESSFUL FUZZY FRONT END

Various scholars agree that the activities undertaken during the fuzzy front end provide a clear understanding of the product considered for new product development, which could ultimately lead to a competitive advantage in the later stages of product development (Cooper & Kleinschmidt, 1995; Kuczmarski & Associates, 1994; Reid & de Brentani, 2004; Smith & Reinertsen, 1991; Urban & Hauser, 1993). Moreover, spending time on activities in the fuzzy front end ultimately leads to saving a large amount of time during product development as well as expenses (Smith & Reinertsen, 1991). In order to be successful during the fuzzy front end and to reduce the probability of straying from the strategy defined for new product development, particular elements or factors need to be complied to. The scholars have identified several factors as the key success factors for a successful fuzzy front end process (Table 3). These success factors are seen as foundation elements, which are contextual variables that provide a coping mechanism for the fuzzy nature of the fuzzy front end.

These elements (Table 3) all need to be in place while moving through the fuzzy front end of new product development. It is clear that strategic considerations in terms of the product itself, the product portfolio and the division of organizational roles are crucial to take into account in order to save time and expenses during the new product development stages. Moreover, a clearly defined plan of product development, including planning, risk mitigation strategies and resource allocation, is very important in terms of minimizing straying from the defined strategy for product development. The following paragraph will indicate the success factors that are relevant for the development phase following the fuzzy front end.

Table 3. Success factors for a successful fuzzy front end.

FFE success factor	Description	Source
Product strategy definition	Strategic vision for the product aligned with the company, including a product-platform strategy and product-line strategy	(Bacon, Beckman, Mowery, & Wilson, 1994; Khurana & Rosenthal, 1998; McGrath, 1996)
Portfolio strategy definition	Strategic vision for the complete product portfolio aligned with the corporate strategy	(Cooper & Kleinschmidt, 1995; McGrath, 1996)
Organizational (team) roles	Identification of a project team, the manager of the team and the designated funds, including a clear division of responsibilities	(de Brentani & Reid, 2012; Griffin, 1997; Khurana & Rosenthal, 1998; Trueman & Jobber, 1998)
Product definition	Clearly defined product specifications, market structure and customer needs, including the value proposition	(Cooper & Kleinschmidt, 1995, 1997; Cooper, 1990; Khurana & Rosenthal, 1998)
Project planning	A well-defined planning for new product development considering resources, contingencies and skills required	(Belliveau et al., 2004; Griffin, 1997; Khurana & Rosenthal, 1998; Reid & de Brentani, 2004)

SUCCESS FACTORS FOR SUCCESSFUL NEW PRODUCT DEVELOPMENT

The success factors (or foundation elements) from the fuzzy front-end resonate in the actual development phase of the new product. The fuzzy front-end influences the success or failure of new product development greatly, though the development phase still needs to comply to certain success factors specific for that stage (Table 4). Many success factors may be named for each stage of new product development. As the focus lies on the fuzzy front end, merely general categories of new product development success factors are listed.

As becomes clear from Table 4, the success factors for the actual development phase of a new product revolve around the organization of the project and the outcomes from in-between assessments. Therefore, the definition of the product and its development strategy is mostly provided in the fuzzy front end, which is validated during the development phase.

3.3 FUZZY FRONT END ASSESSMENT FACTORS

As became clear from section 3.2, the success of the product development phase largely depends on the success of the fuzzy front end. If early assessments of the potential of new products are conducted, the chance of succeeding in developing a promising product increases. In order to provide a foundation of required information for these assessments, a list of assessment measures or factors is identified. Literature is scattered with factors that are considered in the assessment of the potential of new products during the fuzzy front end of product development. Moreover, DSM already uses certain assessment factors in assessment studies. The following sections will structure the resulting list of factors by dividing these factors into four categories, based on the internal environment of the company and the external environment of the company, as well as market factors and technology factors. By doing so, the following factor characterizations are obtained:

- Internal market factors

- External market factors
- Internal technology factors
- External technology factors

Table 4. Success factors for a successful development phase.

NPD factors	Description	Sources
The NPD process	The development process itself considers the importance of market orientation, customer orientation, technological performance and productivity, etc. Assessment factors become important in measuring the success of the process.	(Cooper & Kleinschmidt, 1995, 1997; Cooper, 1990; Griffin, 1997; Reid & de Brentani, 2004)
Organization	The project organization entails the composition of the NPD team, the supervision of this team, commitment of employees and communication, both within and outside of the team	(Boeddrich, 2004; de Brentani & Reid, 2012; Khurana & Rosenthal, 1997, 1998; Tatikonda & Montoya-Weiss, 2001)
Culture	The organizational culture considering entrepreneurial tendencies, risk-taking behavior and innovative behavior	(de Brentani & Reid, 2012; Griffin, 1997; Khurana & Rosenthal, 1997; Reid & de Brentani, 2004; Trueman & Jobber, 1998)
Senior management commitment	This success factor includes the support from senior management and appropriate resource allocation	(Clark & Fujimoto, 1991; de Brentani & Reid, 2012; Zhang & Doll, 2001)
Strategy	The strategy employed for the direction the project is taken, including product positioning, in line with corporate strategy	(Brown, Dixon, Eatock, Meenan, & Young, 2008; Cooper & Kleinschmidt, 1986, 1995, 1997; de Brentani & Reid, 2012; Khurana & Rosenthal, 1997)

3.3.1. Market factors

The assessment factors that are related to the market are divided into two categories: the internal market factors and the external market factors. Both provide insight into the required information considering the market from inside of the company and outside of the company.

Internal market factors

The internal market factors are listed below:

Strategic fit

This factor is defined as the product's fit with the strategy employed by the firm. This strategy can take on different levels: product level, product portfolio level, ranging up to corporate level (Carbone et al., 2012). Strategic alignment is critical for the positioning of the product in the organization (Bart & Pujari, 2007; McGrath, 2001; Ottum & Moore, 1997) and for planning the portfolio respective to the strategy (Cooper, Edgett, & Kleinschmidt, 1997; Reinertsen, 1999; Schmidt & Calantone, 1998).

Network fit

The fit with the organization's network considers the network the company has with its current suppliers, distributors and customers. It is closely related to the factor *business overlap*, though network fit is more related to the relational connections rather than the structure of the network. This factor is of importance in assessing a product's potential, as external partnerships enhance the success of new product development (Faems, Van Looy, & Debackere, 2005; Ozer & Cebeci, 2010).

Business overlap

The degree of business overlap is the degree to which the existing supply chain organization can be utilized for the product to be developed and the fit with the running business activities. This organizational factor positively impacts the success of new product development, as it determines to which extent the organization is already equipped in realizing commercialization (Millson & Wilemon, 2002; Tatikonda & Montoya-Weiss, 2001).

Resource availability

The availability of resources is related to the degree of access to raw materials for the development of products. These resources are not related to financial resources. The availability of resources can be a challenge in the case when these resources are rare, but can create a large competitive advantage to the organization if these are diversifying and valuable (Cooper & Edgett, 2003; Cooper & Kleinschmidt, 1988).

Financial resources

The budget the company can allocate to the new product development process is critical in determining the product's success, as it determines the activities that can be undertaken and the size of the team that can work on the project (Cooper & Edgett, 2003; Cooper & Kleinschmidt, 1988; Khurana & Rosenthal, 1997).

Addressable and attainable market size

DSM distinguishes two types of market sizes: addressable and attainable. This factor considers the size of the potential market that may be targeted by the firm relating to the product. The addressable market size definition can be based on demand volume or revenues. The attainable size of the market is more detailed than the addressable size: the attainable size is based on the addressable size, but includes the production capacity that can be realized by the company.

Market share

The share that a company can obtain within the market determines the company's position relative to its competitors (Ottum & Moore, 1997; Ozer & Cebeci, 2010). This factor needs to be considered together with the market size that can be addressed and attained: the market share can be large, but the corresponding market size could be small relative to the revenue goal set by the organization.

Market newness

The newness of the market to the company in which the new product is positioned is of high importance in discontinuous innovation projects (McMurray & Jones, 2003). Within DSM, this type of newness is one of the key parameters in determining whether a project is included in the portfolio of the Business Incubator.

External market factors

The external market factors are listed below:

Competitive intensity

The intensity of competitors considers the concentration of competitors in the targeted market. This is one of the most important market factors to consider, as it determines for a large part whether commercialization is feasible with the product to be developed (Brown et al., 2008; Schroder & Jetter, 2003; Zhang & Doll, 2001).

Customer landscape

The customer landscape takes into account the concentration of potential customers within the targeted market, both existing and potential. As inter- and intra-organizational collaborations are crucial within the fuzzy stages of development (Carbone et al., 2012; Faems et al., 2005), this factor determines the company's chances to obtain external partnerships.

Customer acceptance

The acceptance of the new product by the customer considers the degree to which customers are open to adopt the product. This factor is closely related to the factor *attitude towards change*, but differs in the sense that *customer acceptance* refers to the product itself.

Attitude towards change

The market openness towards change is similar to the factor *customer acceptance*. It differs from the acceptance factor in terms of the focus: the attitude towards change is directed to the possibility that production processes of the company's (potential) customers can change based on the new product and the customer's willingness to do so. This depends on the perceived increased performance of the product versus the degree of changes to be made.

Innovativeness of the market

The degree of innovative behavior in the market determines the threat of new entrants into the targeted market (McMurray & Jones, 2003). If innovativeness is low, the likelihood of new entrants entering this market is low, while with high innovativeness more entrants enter and exit the market. Also, incumbent firms can be intrinsically innovative. This factor is closely related to the rigidity of the industry.

Industry rigidity

The industry rigidity is the degree to which the industry structure may be changed. This factor is closely related to the factor *innovativeness of the market* and determines the dynamics of the targeted market. Industry rigidity specifically refers to the lock-in of certain products into the market and therefore, competitors producing these products. In other words, entry barriers are crucial in this factor (Bond & Houston, 2003).

Market growth

The degree to which the market is growing is crucial in estimating the future cash flows for the company when a new product is developed. It is used most frequently by DSM as an indicator of project feasibility. Market growth is usually measured in Compounded Annual Growth Rate (CAGR), which is a percentage at which the market grows each year.

Installed base size

The size of the installed base is amount of customers and end-users that have adopted the product, or will potentially adopt the product (Schilling, 2012). In discontinuous innovation projects, this factor becomes less important, as the installed base does not exist. However, it can provide an indication in the potential size of the installed base in similar products.

Customer need intensity

The need intensity of the customer for a new product is one of the most frequent factors considered by DSM in the earliest stages of product development. This factor assesses whether the new product fulfills a burning need of the customer, or whether this need is nothing more than a mere ‘itch’. In the latter case, a discontinuous product will most likely not succeed.

Environmental trends

The degree to which trends considering the environment exist, which may be beneficial considering the product in question. However, the sustainable nature of a new product is not the differentiating factor in most cases: an improvement in performance compared to other products is most important, while a green label is a ‘nice-to-have’ feature.

Political factors

Political factors relate to the political and social situation within the targeted market. If the targeted market is characterized by lobbying and corruption, the market will be difficult to enter.

3.3.2. Technology factors

As was the case for the market factors, the factors revolving around information on the technology can also be divided into internal technology factors and external technology factors. These will be explained below.

Internal technology factors

The internal technology factors are listed below:

Competences fit

The fit with the company's competences refers to the product's fit with the (core) competences of the firm, in both a tangible and intangible sense. In-house competences can significantly increase the competitive position of an organization, as the corresponding knowledge within these competences is specialist and unique (McGrath, 2001; Schilling, 2012). Examples of these competences are in-house technologies and knowledge of the targeted part of the value chain. This factor is not to be confused with *business overlap*, as these competences refer to the internal technological situation, whereas business overlap is market oriented. As competences may not be present in-house, organizations can obtain these competences from collaborations as well (Faems et al., 2005; Liebeskind, Oliver, Zucker, & Brewer, 1996).

Performance characteristics

The characteristics of the product in terms of its performance compared to other products in the targeted market is important in order to position the product into this market. This is the main technological factor that determines the positioning strategy of the new product (Cooper & Kleinschmidt, 1997; Tatikonda & Montoya-Weiss, 2001).

Productivity

The productivity relates to the efficiency of the production process, i.e. the product yield obtained by the process. Efficiency should be as high as possible in order to have a cost-effective process.

Costs

The costs relate to the complete process of developing the product, including the early stages of the development process. This factor is important in order to assess the amount of financial resources that are required to complete the process.

Intangible resources

In-house knowledge and know-how, or the ability to obtain external knowledge and know-how, is crucial to determine whether the firm is equipped for developing a new product. Intangible resources are closely involved with the learning curve the company can have during the development process (Faems et al., 2005; Schilling, 2012).

Physical resources

In contrast to intangible resources, the tangible or physical resources entail technologies or even facilities that are present in the organization. This factor is therefore closely related to *competences fit* in terms of the equipment related to the competences.

External technology factors

The external technology factors are listed below:

IP landscape

The Intellectual Property (IP) landscape considers the degree to which the new product and its characteristics are protected by other parties. If the new product to be developed is completely blocked in terms of intellectual property, the development is not feasible. However, in discontinuous innovation projects the IP landscape should generally be low, as these entail new products to the market.

Regulatory landscape

The existence and degree of strictness of governmental regulations and laws in the targeted market is important to consider in terms of the development time of the product. If regulations are very strict, the procedure for approval of using the product in the targeted market can be time-consuming.

Product newness

This factor considers the newness of the product to both the market and the company (McMurray & Jones, 2003). It is therefore both an internal and an external factor. It is placed as external, as the newness of the product to the market implicates the most uncertainties and challenges in the commercial success of the product. It is one of the ‘newness’ factors that is considered at DSM for early assessment of new projects.

Technology newness

The third ‘newness’ factor considered at DSM is technology newness, which implicates the newness of the technology used for development/production for both the company and the market. In the end, in order to be included in the portfolio of the Incubator, a new product needs to be assessed as new in two factors (market, product and/or technology).

Product maturity

The maturity of the product is considered as the stage of the product life cycle where the new product finds itself (Schilling, 2012). The new product is in the earliest stages of the life cycle when it concerns a discontinuous innovation. This factor is related to the *product newness*, but differs on the notion that maturity is related to the stage of development of the product, instead of its degree of newness.

3.3.3. FACTOR MATRIX

The categorization of the factors into four categories allows for these factors to be put into a matrix (Table 5). By doing so, making a distinction between the factors is facilitated. The number of factors in each category varies significantly, which indicates the varying degrees of complexity in each factor category. For instance, the majority of market factors is characterized as relevant for ternal environment of the company, meaning that the external environment is crucial to er in market assessments. Furthermore, the technology factors are mostly related to the internal environment of the company. This shows that the capabilities within the companies are more important considering the technology compared to the external environment.

Table 5. The four category matrix

	Market	Technology
Internal	Strategic fit	Competences fit
	Network fit	Performance characteristics
	Resource availability	Productivity
	Business overlap	Costs
	Market size	Intangible resources
	Market share	Physical resources
	Financial resources	
nal	Market newness	
External	Competitive intensity	IP landscape
	Customer landscape	Regulatory landscape
	Customer acceptance	Product newness
	Attitude towards change	Technology newness
	Innovativeness market	Product maturity
	Market growth	
	Installed base size	
	Customer needs	
	Environmental trends	
	Political factors	
	Industry rigidity	

3.4 CURRENT FUZZY FRONT END MODELS

In literature, a wide range of fuzzy front end model can be found, which vary from stage-gate models to circular, holistic models. Carbone et al. have written a literature review on this variety of models (Carbone et al., 2012), of which a summary is provided in Table 6. As the models presented here are merely a selection of the models found in literature, one could conclude that a lack of consensus on the best practice for the fuzzy front end is the source of the wide model variety. This section will present the possible sources of the lack of consensus, along with a more detailed description of the most discussed models in literature. Afterwards, the models will be evaluated on their strengths and weaknesses.

3.4.1. LACK OF CONSENSUS IN FUZZY FRONT END MODELS

From the descriptions provided for each model, one can conclude that no consensus exists on the models that are currently presented in literature. This lack of consensus is caused by multiple factors that can be distinguished from the different scholars who have proposed the models.

START AND END OF THE FUZZY FRONT END

The start of the fuzzy front end from the perspectives of the scholars varies significantly. As indicated in Figure 2, the start of the fuzzy front end is defined as the identification of an opportunity, while it ends when the idea moves into the development phase. Not all scholars presented here maintain this definition. For instance, Kim and Wilemon argued that the fuzzy front end is the process of idea generation, which ends with the identification of an opportunity that is documented (Kim & Wilemon, 2002b). In turn, the development phase starts with the screening of the feasibility of this opportunity. This is not in line with the definition presented in chapter 2 of this work. In contrast, Smith and Reinertsen skip the idea generation and screening, as they have moved straight to the formulation of a project proposal for the innovation (Smith & Reinertsen, 1991).

The scholars that have kept the definition of the fuzzy front end in their phase/stage descriptions as defined in this thesis work, are Paul (1996), Cooper (1997), Khurana & Rosenthal (1997) and Koen et al. (2001).

FLEXIBILITY

Another source of the lack of consensus in the presented works is the amount of flexibility that is applied to the proposed models. The stage-gate and phase models are designed to reduce uncertainty and structure the fuzzy front end, while Koen et al (2001) have presented a model that encourages flexibility due to its circular nature.

LEVEL OF DETAIL

The last factor leading to the lack of consensus in the models is the level of detail that is considered in the formulation of the stages or phases. Koen et al. (2001) provides a total of five phases, which each focus on a specific target to be met. On the other hand, Cooper (1997) has merely defined two, which lack level of detail in the activities undertaken.

3.4.2. THREE MODELS EXPLAINED

Based on the factors leading to the lack of consensus, three of the discussed models will be discussed in more detail in this section. The decision to consider three of these models in further detail is based on the following aspects:

- The level of conformity to the definition of the fuzzy front end process as posed in chapter 2 of this thesis work;
- The varying nature and level of detail of the remaining models.

Table 6. An overview of the variety of models proposed for the fuzzy front end. Adapted from Carbone et al. (2012)

Authors	Model type	Description
Smith & Reinertsen (1991)	Stage-gate model	1. Project proposal 2. Business plan 3. Detailed project plan and product specifications
Paul (1996)	Phase model	1. Idea screening 2. Concept development and testing 3. Business analysis
Khurana & Rosenthal (1997)	Phase model	1. Opportunity identification; initial market and technological assessment; strategy benchmarking 2. Product concept development 3. Product definition and planning
Cooper (1997)	Stage-gate model	1. Preliminary investigation 2. Detailed investigation and business case preparation
Kim & Wilemon (2002a)	Phase model	1. Capturing idea generation 2. Screening of ideas 3. Evaluation and documentation of decisions
Koen et al. (2001)	Holistic model	Circular model with feedback loops, with the following stages: • Opportunity identification • Opportunity analysis • Idea generation & enrichment • Idea selection • Concept definition

As indicated in section 3.4.1, the models presented by Smith & Reinertsen (1998) and Kim & Wilemon (2002) do not conform to the fuzzy front end definition maintained in this thesis work. Therefore, these models will not be considered in more detail. Moreover, when considering the common characteristics of the models, the phase model proposed by Paul is very similar to the phase model presented by Khurana & Rosenthal (Table 6) (Khurana & Rosenthal, 1997; Paul, 1996). As the latter have a more detailed model including a benchmarking mechanism with the strategy maintained by the organization, this phase model will be selected for discussion, along with the stage-gate model proposed by Cooper (1997) and the holistic model from Koen et al. (2001).

Stage-Gate model

The stage-gate model presented by Cooper is the most widely known and used model for moving through new product development (Cooper, 1990). The PMP approach that is used by all business groups within DSM is based on this stage-gate approach, indicating that large organizations have valued the contribution that Cooper has made with his model. A schematic representation of the stage-gate model is presented in Figure 6.

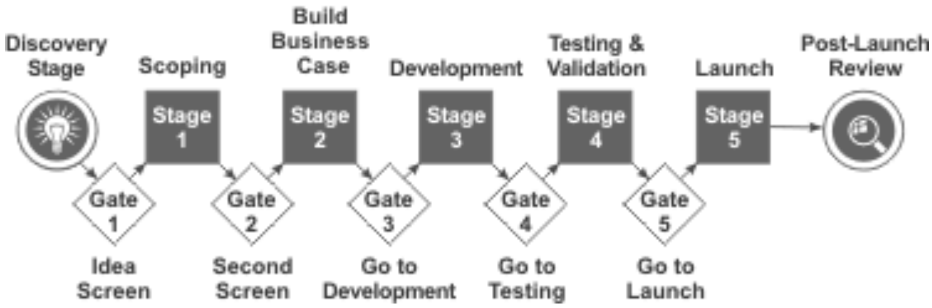

Figure 6. A schematic representation of the stage-gate model proposed by Cooper. The fuzzy front end entails the stages 1 and 2. Source: Cooper (1990).

Cooper has identified two main stages for the fuzzy front end: the scoping of an idea and subsequently, building a business case on the idea. After each stage, a decision gate is positioned which serves as a checkpoint before moving into the next stage of development. Therefore, the model provides structure in the sense that stages are defined, which are closed by delivering a product and making a rational decision based on that deliverable.

Though Cooper's model provides a structured way of moving through the fuzzy front end, this model is based solely on incremental innovations (Reid & de Brentani, 2004). This means that the amount of uncertainty is less as compared to disruptive innovation processes. Moreover, with incremental innovations one assumes that the overall strategy within the product portfolio or the product itself remains unchanged throughout the development process, which is not the case for disruptive innovations. Furthermore, the level of detail in the phases is low and the formulation of the stages is quite broad, which does not provide an indication in the type of information needed to build a decision upon. Lastly, incremental innovation processes function well in highly structured processes, while disruptive innovations need a degree of flexibility due to the probability that the development strategy can change when new information surfaces.

In conclusion, the structured nature of the stage-gate model is in itself useful in order to have clearly defined deliverables at the end of each stage and regular checkpoints. However, the model is merely suitable for incremental innovations due to the lack of flexibility needed for disruptive innovations.

Phase model

Based on the stage-gate model developed by Cooper, Khurana and Rosenthal have developed a phase model, which provides more information on the requirements for having a successful fuzzy front end process (Khurana & Rosenthal, 1997). A schematic representation of their model is provided in Figure 7.

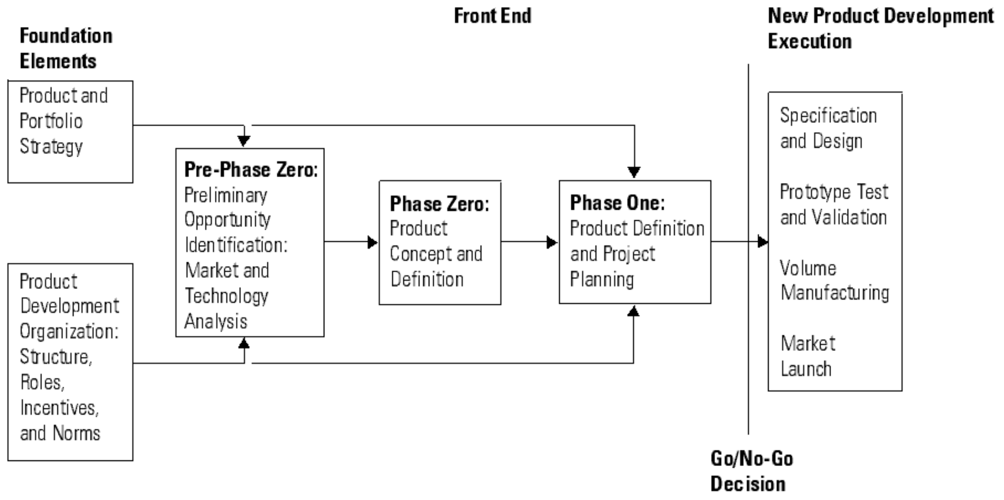

Figure 7. A schematic respresentation of the phase model proposed by Khurana & Rosenthal. Source: Khurana & Rosenthal (1997)

Khurana & Rosenthal's phase model takes into account the organizational context of the company in terms of portfolio strategy en organizational roles. The authors emphasize on the importance of having a well-structured organization in place before moving through the fuzzy front end. Both elements are used as a benchmark in each of the phases of the proposed model. Moreover, the phases offer an even more structured way of moving through the fuzzy front end, while still maintaining some flexibility in the sense that organizational roles and strategy benchmarking are involved.

However, some disadvantages of the model can be named:

- As was the case with Cooper's model, no information is provided on the assessment activities that are undertaken in each phase, let alone the type of information required to reach a decision;
- No decision-making moments are implemented in the model in between the phases: the only decision-gate is placed at the end of the fuzzy front end, when a 'go' or 'no go' decision is made to move to the product development phase. These moments are crucial in order to have regular moments of control considering the feasibility of the product or idea;
- Decision-making roles within the organization for each phase are not defined, while these are important when taking into account the organization around the fuzzy front end in a company.

Holistic model

The holistic model proposed by Koen et al. is not based on any of the presented stage-gate or phase models in literature (Koen et al., 2001). This model offers a circular way of thinking when moving through the fuzziness. The model is presented in Figure 8.

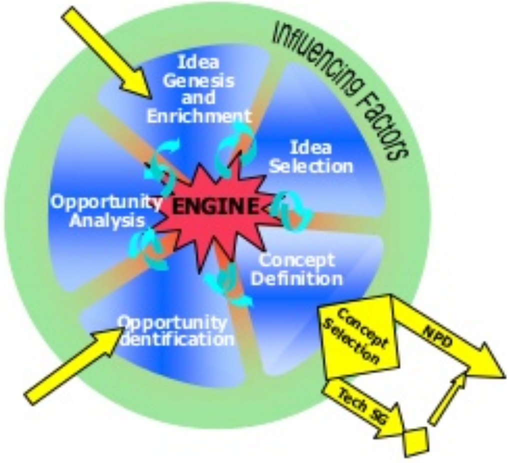

Figure 8. A schematic respresentation of the holistic model presented by Koen et al. (2001). Source: Koen et al. (2001)

Koen et al. have developed a model that is completely based on flexibility and an ever-changing environment. They argue that organizations cannot influence the outcomes of each phase in their model due to the existence of influencing factors. These are factors from outside of the organization, which the organization cannot control, but will still influence the feasibility of the innovation at hand. In the model the flexibility is maintained by providing the opportunity to continuously switch from one phase to the next and backwards. By doing so, any new discoveries in any of the phases can cause the project to take a step back. Eventually, a concept definition is the final product of this model (Koen et al., 2001).

For disruptive innovations, the existence of flexibility is a major asset when considering the holistic model. However, some disadvantages can be named to this model:

- As was the case with the stage-gate and phase model, no decision-making roles are assigned;
- No benchmark with strategy is made explicit in this model;
- The model does not provide a clear ending of the process. If one wishes to gain more information on the project, it is still possible, but the danger is that the process will run continuously. This can result in a lack of time-efficiency and deciding when sufficient amounts of information are gathered for decision-making. Though the flexibility is a major advantage, it may also be the downfall in this case.

3.4.3. Conclusion

Based on the description of the three fuzzy front end models proposed in section 5.1.2, strengths and weaknesses to each model can be summarized (Table 7). Next to the specific advantages and disadvantages coupled to each model, a few general points of attention can be listed for all three models:

- Neither of the models consider the decision-making roles involved in the process of moving through the fuzzy front end. Khurana & Rosenthal have indicated that project roles are crucial to obtain a successful fuzzy front end, but have not mentioned on what level of the organization these project roles are assigned;

- The models lack a detailed description of the type of information needed in order to produce the deliverables stated at the end of each phase. These deliverables serve as the basis for making the decision.

These general points of attention will be addressed in this thesis work by implementing the decision-making roles identified within the DSM Innovation Center and by allocation of assessment factors to each phase of the resulting model. The manner, in which this will be performed, will be discussed in chapter 4 and chapter 5, respectively.

Table 7. Advantages and disadvantages of the stage-gate model, the phase model and the holistic model.

Model	Advantages	Disadvantages
Stage-gate	• Step-wise approach • Decision gates	• No strategy alignment • No feedback loops • Lack of flexibility
Phase	• Step-wise approach • Organizational context • Strategy alignment	• No feedback loops
Holistic	• Feedback loops • Flexible	• No strategy alignment • No clear end

From this analysis, the models presented display similarities in the type of phases/stages that are implemented, but taking these models together, they may compensate for the deficiencies in each of the models:

- The general organizational context from Khurana & Rosenthal that is lacking in Cooper's model;
- The decision-gates in Cooper's model that are lacking in the models proposed by Khurana & Rosenthal and Koen et al.
- The flexibility of Koen et al.'s model that lacks in the stage-gate model and the phase model, which is caused by the presence of feedback loops in the model.

3.5 SETTING THE MODEL REQUIREMENTS

Based on the theoretical framework presented in this chapter (sections 3.1 to 3.4), a set of requirements can be defined, which the structured fuzzy front end model needs to comply with. These requirements are based on the following aspects:

- **Activities within the model should be related to both technological and market information gathering.** The models presented in section 3.4 incorporate these activities. This is especially important when assessing products from a high-technology industry, such as the biotechnology industry: due to the technological nature of the innovation, its positioning into the relevant market segments should be based on its technological specifications and performance. Cooper has emphasized the importance of these activities with an empirical study, which concluded that a company's success in new product development depends on the quality of execution of the 'pre-development activities', meaning the fuzzy front end (Cooper, 1994).
- **Effectiveness of the model is of high importance.** The quality of the execution of the fuzzy front end depends strongly on the quality of the activities undertaken within this phase. These activities need to comply with the success factors stated in Table 3. Verworn studied the factors that increase effectiveness of the fuzzy front end. They have concluded that the core driving force for effective fuzzy front end activities is the *intensity of initial planning* (Verworn, 2009), which entails the planning of activities to be undertaken (Dvir & Lechler, 2004; Shenhar, Dvir, Levy, & Maltz, 2001). According to the results obtained by the authors, this factor has a positive impact on the reduction of both market and technological uncertainties (Herstatt et al., 2004; Verworn, 2009). Thus, the reduction of market and technological uncertainties positively impacts the quality of the fuzzy front end execution, with an indirect impact of intensity of initial planning.
- **Efficiency of the model is also important.** The efficiency of the structured fuzzy front end is important to consider in terms of the time span of the fuzzy front end activities, as well as the resources allocated to these activities (Cleland, 1994). The efficiency of the activities is positively impacted by several factors (Verworn, 2009):
    - Intensity of initial planning
    - Reduction of technological uncertainties

  Efficiency also directly impacts the effectiveness of fuzzy front end activities (Verworn et al., 2006). Therefore, the efficiency of the structured fuzzy front end model also directly impacts the effectiveness of this model.

In line with these aspects and the literature presented in this chapter, the following requirements for the structured fuzzy front end model need to be in place:

1. The model should be able to reduce both market and technological uncertainty

These two types of uncertainties were highlighted in section 3.1. Both types of uncertainties can be reduced by planning the activities to be undertaken in the fuzzy front end before embarking on the assessment of an innovation. By reducing market uncertainty, the commercial success of an innovation is positively impacted, as knowledge is available on the market characteristics, trends and customer needs. Market uncertainty has a large impact on the success of product development and is more difficult to reduce than technological uncertainties. The reduction of technological uncertainties is beneficial from the perspective of effective planning, as knowledge on the technology and its development is present. Even though the disruptive nature of innovations causes fuzziness in the activities to be undertaken, a structured method of activity planning will reduce some of this fuzziness.

2. Activities within the model should be aligned and benchmarked with the company's strategy on any level.

As was stated in Table 3, two of the success factors of the fuzzy front end involve the definition of a strategy in terms of the product and the company's product portfolio. Both of these factors considered the formulation of a strategic vision aligned to the overall corporate strategy. The alignment with the corporate strategy is important to consider in any type of innovation: if the innovation does not provide the company with its desired position according to its strategy, the project should not be undertaken. While handling disruptive innovations, this means that continuous benchmarking with the corporate strategy is needed, as new information on the innovation can completely change the scope of the project, which can lead to a product strategy that does not comply with the corporate strategy. The model should enable benchmarking activities with strategy.

Another aspect of strategy alignment is the actual formulation of a development strategy during the late stages of the fuzzy front end. Both the stage-gate model and the phase model have shown that by the end of the fuzzy front end, a business case or product definition is required before moving into the development phase (see section 3.4). These elements both contain a development strategy. As explained above, this strategy needs to align with the corporate strategy and the portfolio strategy.

3. Decision-making roles should be clear in the model based on organizational roles within the fuzzy front end.

Another success factor for the fuzzy front end was stated to be a clear division of organizational roles within the process (Table 3). Even though the phase model recognizes the importance of these organizational roles, neither of the models presented in section 3.4 have indicated any reference to a division of decision-making roles within the fuzzy front end. Reid & de Brentani have stressed that with disruptive innovations, the decision-making process involved in crucial due to the amount of uncertainties involved in these innovations (Reid & de Brentani, 2004). This notion is sensible, as limited information is available on disruptive innovations, which makes an appropriate division of decision-making roles important.

4. The model should be easy to use

The stage-gate model presented in section 3.4 is the most widely used model for new product development. The setup of the model is simple with its subsequent stages ended by decision-gates, which makes the model attractive to use within organizations. Therefore, in order for the ultimate structured model to be used at DSM, it should be easy to use by all employees involved in the fuzzy front end, which stimulates the efficiency of the activities undertaken.

5. The model should leave room for flexibility

When handling disruptive innovations, the amount of uncertainties involved implicate that one can never know in advance what the outcome of the fuzzy front end will be. While assessing this type of innovation, new information can come to light in late stages of the fuzzy front end, which can change the development strategy that is formulated. Therefore, the model needs to allow feedback loops in order to move to an earlier phase when needed. This will make the fuzzy front end more effective.

6. The model should be applicable at DSM

As DSM is in need of a structured fuzzy front end model, this model should be suitable for implementation within DSM. It needs to complement the methods used to monitor the progress within new product development. If the model implicates an entire new way of working of the organization, the resistance to adopt the model will be too large.

4. THE FUZZY FRONT END AT DSM

In order to have a basis on which to provide structure into the fuzzy front end, DSM's current process to proceed through the fuzzy front end needs to be explained. This not only includes the steps taken within the process, but also on which basis the decisions are made to further develop new products. This chapter will discuss the findings from the interviews with internal experts at DSM in terms of the decision-making process regarding the fuzzy front end of disruptive innovations (section 4.1) and the current models for new product development used to support this decision-making (section 4.2). Appendix I contains company information for additional reading on the organizational structure within the DSM Innovation Center and the Business Incubator: this can provide more understanding of the positions taken by the interviewees.

4.1 THE CURRENT DECISION-MAKING PROCESS

Insight was gained into the current decision-making process within the Business Incubator at the DSM Innovation Center by conducting interviews with highly positioned employees that are experienced in decision-making considering disruptive innovations. This section will present the methodology with which the interviews were conducted and the general observations from these interviews. Furthermore, the current decision-making process will be explained through derivation from these interviews.

4.1.1. METHODOLOGY

In order to fully understand the current decision-making process, semi-structured interviews were conducted with internal experts involved in disruptive innovation processes at the DSM Innovation Center. Next to a pre-determined set of questions on the steps in the decision-making process and the extent to which the interviewee was involved in (either of) these steps, the semi-structured nature of the interview allowed for spontaneous questions to be asked in response of the answers given by the interviewee. As a result, rich data is obtained on which the decision-making process may be derived. Other methodologies for conducting these interviews were structured interviews and unstructured interviews. With structured interviews, a complete set of questions is prepared for the interview. This is particularly useful when the researcher knows exactly what information is needed from the interviewee. A semi-structured interview is a better fit to this thesis research, as information is already available on the official decision-making method, but the reality of this process can merely be discovered by leaving room for different questions. On the other hand, an unstructured interview would provide this flexibility, but lacks a sense of direction in the questions to be asked.

The semi-structured interviews were conducted face-to-face, which enabled the interviewer to monitor body language and facial expressions during the interview. These can indicate whether the interviewee is open or reluctant to answer the questions, or experiences difficulties with answering the question. Conducting these interviews through telephone would not have given this possibility.

The interviews started with general questions on the interviewee's position and experience, which provides a basis for a background check and makes the interviewee comfortable before starting with the actual interview. Afterwards, general questions were asked in order to sketch a broad overview of the current decision-making process. The questions gain level of depth while progressing through the interview: by the end, the interviewees were asked to specifically indicate the foundations on which decisions are made and the types of information considered.

In total, 7 interviewees were interviewed, who were checked for their background and experience considering disruptive innovation processes. This background check provides an indication whether the data obtained for each interviewee is reliable.

Table 8 lists the position, years of experience in the current position and the background for each interviewee. Respondent 4 has less than one year of experience within the current position at the Innovation Center, but this interviewee has 3 years of experience within a similar position at the corporate venture Bio-based Products & Services. The responses given by this interviewee need to be considered with caution due to the limited time spent at the Innovation Center. The complete interviews are enclosed in Appendix II.

4.1.2. General observations

Based on the interviews displayed in Appendix II, rich results are obtained to create insight into the decision-making characteristics within the Innovation Center and the Business Incubator. This section elaborates on general observations from these interviews. These observations are segmented into several themes, as presented below, in order to structure the findings.

Decision-making in discontinuous vs. incremental innovations

One of the main themes that came forward during the interviews is that the nature of the decision-making process depends on the type of innovation involved, i.e. incremental or disruptive innovation. The distinction between the decision-making processes is mainly caused by the amount of uncertainty that is involved in each innovation type and the impact these uncertainties have on the organization. Particularly respondent 3 emphasized this, by indicating that the intrinsic nature of these innovations causes differences in the decision-making methodology and the types of information are needed in order to reach a decision.

All respondents, except for respondent 6, have stated that next to the factual information needed for decision-making, the actual decision-making is often based on the intuition of the decision-maker. Respondents 1 and 4 have emphasized that this intuition is mostly based on the experience of the decision-maker in such projects. Interestingly, the respondents differ in their opinions on the value of intuition-based decision-making. For instance, respondent 1 has described intuition as a valuable asset in the process, as information on disruptive innovations is scarce. In contrast, respondents 2, 3 and 7 expressed their disappointment in the fact that intuition plays a crucial role, as it is not based on rationality and facts. Moreover, respondent 7 has stated that decision-making within the Innovation Center is often based on 'politics': if the project is owned by an individual who is favored by the decision-maker, this project would more likely move to further development than other projects owned by less favored individuals. This difference of opinion is most likely caused by the positions taken by these respondents in the organization: while respondent 1 is of executive management level and has decision-making power, respondents 2, 3 and 7 have supporting and advising roles in decision-making. Therefore, the need for a rational approach in decision-making is important for the supporting positions, while the actual decision-makers do not believe that rationality is necessary.

Table 8. Experience and background of interviewees at the DSM Innovation Center.

Interviewee #	Position	Experience (yrs)	Background
1	Vice President	2,5	• 30 years at DSM, starting in R&D • Over the years the interviewee has worked in almost every discipline in DSM (HR, new business development, supply chain, etc.) • Last 5 years focus on innovation management
2	Project Director	3	Responsibilities: • Project management within one emerging business area in the Innovation Center • Starting new corporate ventures in the Innovation Center • Portfolio management in the Innovation Center
3	Innovation Process Manager	4	Responsibilities: • Collection and implementation of best practices in innovation management inside and outside of DSM • Provide support to the Innovation Council
4	Program Director	3	• Many years of experience in R&D and innovation management in previous positions in other departments • Portfolio and project management within the corporate venture Bio-based Products & Services
5	Business Manager	6	• Around 20 years of experience at DSM: project management, business development and innovation management • Responsibility: setting up new business ventures in nutrition
6	Business Development Manager	6	• 26 years of experience within DSM: R&D, sales and business development • Responsibility: development and commercialization of one product within the venture
7	Innovation Excellence Manager	3	• 7 years of experience within DSM: marketing & sales and innovation management • Responsibility: facilitating innovation processes and development of best-practices

While respondents 1 and 4 indicated that the intuition of the decision-maker is based on his or her experience and situation recognition, other respondents indicated that this experience is obliterated and inapplicable in disruptive innovations. Respondents 2 and 3 stated that the newness of disruptive innovations makes the involved individuals explore unknown territory, including the decision-makers. Experience and situation recognition are not relevant, as completely new situations occur when managing disruptive innovations. However, for incremental innovations experience-based intuition is very important, as separate situations within these innovations show similar characteristics and outcomes. Respondent 3 has indicated that experience is merely relevant if it is gained through years of involvement in disruptive innovation management, as that yields experience in managing uncertainties. This respondent also compared intuition-based decision-making with psychology: if an individual is presented with a familiar situation and has associated positive feelings to that situation, intuition drives the decision-making process. According to respondent 3, the impact of psychology should not be underestimated in these processes.

Venturing vs. new product development

When asked about the currently used methodology for decision-making, the respondents provided different answers. Respondents 1 and 3 mentioned that the Bell-Mason approach was used, which was taken from 'venture-thinking'. However, other respondents have indicated a different approach: respondents 4, 5 and 6 mentioned the PMP framework, which is used in the complete DSM organization and is based on the perspective of new product development phases. Respondent 4 has stated both approaches are used simultaneously, though more emphasis is put on the PMP approach. The characteristics of these approaches are discussed in more detail in section 4.2. Respondent 2 and 7 did not mention either of these methodologies to be used, but both described decision-making roles in the process. Respondent 7 emphasized on the politics of the process, which were discussed previously.

Respondent 1 emphasized that the Bell-Mason approach is suitable for the situation at the Business Incubator. This respondent strongly believes that the deliverables set in this approach stimulate 'venture-thinking' within the Incubator, which is needed in managing disruptive innovations. When asked about flaws in this approach, respondent 1 indicated that this 'venture-thinking' is where the flaw is detected: the approach was designed for entrepreneurs who seek funding with venture capitalists, while within the Innovation Center the ventures are corporate and operate on yearly budgets. Moreover, according to respondent 1, this approach is strongly process-driven: every time one has a new idea, one needs to move through all phases from beginning to end, which is time- and resource consuming. Respondent 3 also stated the advantage of 'venture-thinking' resonating from the Bell-Mason approach, but indicated that this method has not been officially implemented as a best practice thus far.

Respondents 4, 5 and 6 have described the PMP framework as the current decision-making method. Respondent 5 mentioned that the strength of this method is that the division of roles for each involved individual is clear. PMP merely functions well in business groups within DSM that are involved in incremental innovations. However, for the innovations involved in the Business Incubator, it is less suitable. The reason for this lies in the following four aspects:

- Within the business groups, all projects serve one goal with a defined strategy. The projects executed in the Business Incubator each differ in nature and therefore, also strategy;
- PMP does not consider input from the external environment, while this is of extreme importance for disruptive innovations;
- Technological specifications are important from the start of the process with disruptive innovations, while these are discussed in later stages of PMP;
- PMP offers a strict way of moving through product development, but the work is still done by people. Therefore, the possibility exists that mistakes are made in the decision-making process, despite of following the PMP method.

Respondent 4 indicated that the coupling of Bell-Mason and PMP would be useful for managing disruptive innovations. Combining the advantages of 'venture-thinking' offered by Bell-Mason and the structured nature of PMP would stimulate the involvement of external partners in the development process, which was stated as missing in the PMP model according to respondent 5.

According to respondent 6, PMP is a useful tool in monitoring the progress of different innovation projects. However, this respondent indicated that the fuzzy front end within PMP is far from structured and clear, convinced that the fuzzy front end is the most important part of determining the success of an innovation. This respondent indicated that a stage-gate approach to this fuzzy front end is important to implement, as this process is currently unstructured. Projects tend to be executed before officially starting the process. Respondent 1 agreed with this statement: this respondent mentioned that in the fuzzy front end, the positioning of a project is often difficult, as activities undertaken by different individuals for the same project are not aligned properly. Therefore, a consistent and structured way of moving through the fuzzy front end is lacking at the Innovation Center. The current PMP approach does not suffice regarding the disruptive nature of the innovations developed.

Difficulty with rating the importance of factors

All respondents experienced difficulties when it came to ranking assessment factors that were mentioned in the interviews. Respondent 1 indicated that decision-making is ultimately based on the complete picture that is presented and the intuition or gut feeling that is created with that picture. Moreover, respondent 2 indicated that this intuition-based decision-making needs to be reconsidered considering discontinuous innovations: this needs to be more fact-based through validated key assumptions and 'yes' or 'no' questions. This is similar to the principles behind the Bell-Mason approach. According to the same respondent, the fuzziness of the fuzzy front end would then be significantly decreased.

Level of detail in each phase of decision-making

Each stage of the decision-making process needs different levels of detail considering the required information supporting the decision. At the start of the process (mostly idea generation), the level of detail in terms of needed information is quite shallow. When moving through the different stages, the required information becomes more and more detailed. This also means that more assessment factors or criteria come into the picture when moving through the process. Respondent 1 emphasized on the varying degree of detail when moving through the fuzzy front end: this respondent stated that the early phase of the fuzzy front end entails exploration of the idea, while later on in the fuzzy front end, quantifiable information becomes more important.

Difference in roles in the decision-making process

The respondents each turned out to have a different role in the decision-making process. Respondent 1 was the actual decision-maker at some stages of the process, while the others had a supporting and data-gathering role in order to facilitate the decision-making. The level of support provided also varied between the supporting respondents: some were in charge of data collection, while others gave advice on best practices within decision-making. The difference in the decision-making roles is further discussed in section 4.1.3.

Difference in decision-making methodologies in various business units

Currently, two methodologies are used in the Business Incubator as decision-making measures: the Bell-Mason methodology and the Project Management Process (PMP). These methodologies are used simultaneously, which creates confusion on the definitions on the phases involved in each of the methods. The respondents emphasized on the different methodologies used by different divisions within the Innovation Center. For the scope of this research, the two methodologies used by the Incubator are used as further references. The properties of these methods are discussed in more detail in section 4.2.

4.1.3. Characteristics of the decision-making process

Next to insights into the currently used new product development methodologies and the basis on which decisions are made, the decision-making process within the Incubator can be mapped in a stepwise manner. This stepwise process is based on the following statements derived from the interviews:

- The methodologies for decision-making within the Incubator are the Bell-Mason framework and the PMP approach. Both are used simultaneously or even as part of one another. Respondent 1 has indicated that the key methodology for the Incubator when considering decision-making is Bell-Mason, as the projects within this department have the potential of becoming emerging business areas (or corporate ventures). However, respondent 3 indicated that this is not officially implemented as a best practice. Therefore, Bell-Mason is used unofficially. Moreover, through internal communication with the business analysts within the Incubator (who have an executing role), three out of four have not heard about this framework and thus do not use it. Respondents 1, 3 and 4 have indicated that it is advised to use it, as ‘venture-thinking’ is beneficial in assessing disruptive innovations.

- The decision-making power after each completed phase lies with the portfolio owners or venture steering groups, while the decisions are supported by information gathered by the Project Management Office and best practice advice from the Innovation Program Office. Moreover, each team member within the Incubator has his/her own project and plays the project-executing role in this process. Based on the various parties involved in the decision-making process, specific decision-making roles can be assigned to each of these parties, as presented in Table 9.

Table 9. The decision-making roles for each party involved in decision-making at the Incubator.

Individual	Role	Role description
Vice President	Decider	• Portfolio owner/manager within the Incubator • Decision-making power considering moving from one stage to another in the Incubator • Member of the Innovation Council
Innovation Program Office	Consulted	• Advise on best practices in decision-making • Consulting services to the departments within the Innovation Center • Innovation process facilitation is the key responsibility
Program Management Office	Supporter	• Information gathering for decision-making in the Innovation Council • Presentation of supporting material to the Council
Manager Business & Market Intelligence	Approver	• Team leader of the Incubator team of Business Analysts • Ensures that progress is made with the projects • Supports the decision of the VP
Business Analyst	Supporter	• Execution of the projects within the Incubator, including data gathering and analysis • Presentation of the data and suggestions for a strategy to the deciders
Innovation Council	Decider Approver	• The Innovation Council has decision-making power, of which its extent depends on the stage of the project • Most early stages: approver • Later stages: decider
CIO	Decider Approver Informed	• The same holds as for the Council • Informed when minor decisions are made

- The respondents have described a distinction between a formal decision-making process and an informal one, both taking place within the organization. On the one hand, the formality of a stage-gate process (i.e. PMP) is maintained with predefined assessment criteria, while on the other hand the decision-making is strongly influenced by intuition and sometimes even internal politics. This indicates that the ideal state is pictured as a rational decision-making process, while the reality is that this process is of a normative nature.

4.1.4. Information needed in decision-making

When asked about the type of information that is required for well-founded decision-making, the mentioned assessment factors mostly overlapped the ones that were found in literature (see section 3.3). Main observations from the respondents considering the types of information needed for decision-making are presented in this section. In order to structure the reporting, the findings are clustered based on the types of information.

Market Attractiveness

Respondent 1 has mentioned that factors considering the market attractiveness of an innovation are crucial for founding decisions. In particular, the following factors are important to take into account:

- Market size
- Current market players and their size (i.e. the competitive landscape)
- Market growth
- Dominant business model in the market
- Unmet need in the market

This respondent stated that these factors are important in early as well as late stages of the fuzzy front end, but vary in the level of detail attached to these factors. For instance, in the early stages of the fuzzy front end, a qualitative sketch is sufficient, while later on, the respondent should be able to list names of experts in the targeted market.

Respondent 2 also stated market attractiveness, but has done so in a different manner. The types of information needed in order to determine whether the market is attractive, are the following:

- The potential of the innovation to substitute other, existing products
- Differentiating factors of the innovation compared to other products
- Willingness of the customer to pay more for a product with increased performance or a product with a particular combination of properties

A clear difference is observed in the way these two respondents have approached the attractiveness of the market. Respondent 1 is clearly interested in the commercial aspects of the innovation, while respondent 2 has focused more on the positioning of the technological aspects into the market, considering the needs of the market. The perspective taken by respondent 3 was aligned with the perspective of respondent 1 in the sense of the commercial mindset, though respondent 3 emphasized on a financial target to be met within 5 years. Due to confidentiality reasons, this target is not mentioned.

Technological attractiveness

Next to the market attractiveness, respondent 1 has mentioned the technological attractiveness of the innovation. The following types of information illustrated this attractiveness:

- The currently used dominant technology
- Technological specifications of the innovation
- Whole-product stack, meaning the services and delivery of the product at the start of the development phase
- Extrapolation of the faults in the currently used technology to the value that DSM can bring (i.e. the potential of substituting this technology)

Respondent 2 has indicated similar factors as being important to assess the market attractiveness of an innovation: the potential to substitute current technologies with the innovation at hand was mentioned by both respondents. This is highly correlated with the differentiating factors of the innovation developed at the company, as this determines whether an innovation will be successful.

DSM Fit

Respondents 2 and 3 have indicated that the fit of the innovation to DSM is deemed as important in assessing the potential of innovations during the fuzzy front end. Respondent 2 stated that this should be mentioned, but it is a wild assumption that a disruptive innovation should match the competences present within DSM. Many projects have been incorporated within the Innovation Center that did not resemble any other efforts attempted before. DSM fit is therefore not important. Instead of the fit to DSM, the business case presented at the end of the fuzzy front end is most important to consider, according to this respondent. This case is built upon different factors that assess both market attractiveness and technological attractiveness of an innovation.

In contrast, respondent 3 said that the fit to DSM is indeed important. This fit is considered in terms of the question whether DSM is able to realize successful development and commercialization of the innovation. Whether the innovation will be successful strongly depends on the factors determining market attractiveness and technological attractiveness. Having competences available in-house is not important when it comes to disruptive innovations. However, the ability to attract these competences from outside of DSM, such as development partners or technology licensing, determines whether DSM can execute the development of the innovation. According to respondent 3, the focus lies on the presence of internal competences when discussing the fit to DSM, while for disruptive innovations the focus should be moved to attracting external competences to the company.

According to respondent 5, the involvement of external competences in terms of development partners is crucial for a successful fuzzy front end and ultimately, a successful development of the innovation. Therefore, the DSM fit in terms of internal competences does not provide a relevant discussion; the discussion on which partners to attract is most relevant in disruptive innovations.

4.2 TWO METHODOLOGIES FOR NEW PRODUCT DEVELOPMENT

The respondents of the interviews have indicated that different methodologies are deployed within the Innovation Center and more specifically, the Business Incubator for monitoring the progress of various projects and for decision-making in these projects. These methods are the Bell-Mason approach and the Project Management Process (PMP). Both are based on fundamentally different perspectives, but have similar activities and deliverables. This section will discuss the characteristics of both methods.

BELL-MASON METHODOLOGY

In section 4.1.2, the Bell-Mason methodology was named as the venturing perspective for decision-making. This approach was developed by the Bell Mason Group and was meant to focus on the development of corporate ventures. The model consists of five separate phases, each with its own activities and deliverables (Figure 9).

The Ideation phase serves as an idea-generating phase, where new ideas are identified from for instance market trends or R&D efforts within the company itself. After Ideation, an idea is selected in order to proceed into the Concept phase. This phase concentrates on efforts in order to develop a concept strategy for the development of the idea, which entails the formulation of key assumptions in order to position the product into target market segments. Usually, the individual driving this phase is the (future) CEO of the corporate venture, or the founder with a vision.

After the definition of the concept strategy, the business model is developed in the Seed phase. The strategy for product development is defined in this phase, while validating the key assumptions made on product positioning in the Concept phase. In order to ensure the success of product development, the Seed phase places importance on the installment of development partners, which could be potential customers.

By closing the Seed phase, the actual development of the product is initialized with the Alpha phase. During this phase, all preparations are put in motion in order to prepare a limited market introduction of the product. It is essential to test the performance of the product thoroughly, benchmarked on the requirements of the targeted market segment. One of the major aspects of this phase is to determine the pricing model for the product, which finalizes the business model for the product.

The last phase (Beta) focuses on the validation of the business model developed during the previous phases. This validation is realized by the initial, limited market introduction of the product. The reason for a limited introduction is minimalizing the losses if the product turns out not to be performing as anticipated. By the end of the Beta phase, the product is launched in the market on a large scale.

The key advantage of this methodology, as indicated by the interviewees, is that the deliverables are defined as venture deliverables, where proposals are needed for financing the project. The downside of this model is that it does not take into account the fact that companies work with yearly budgets, which can change every year.

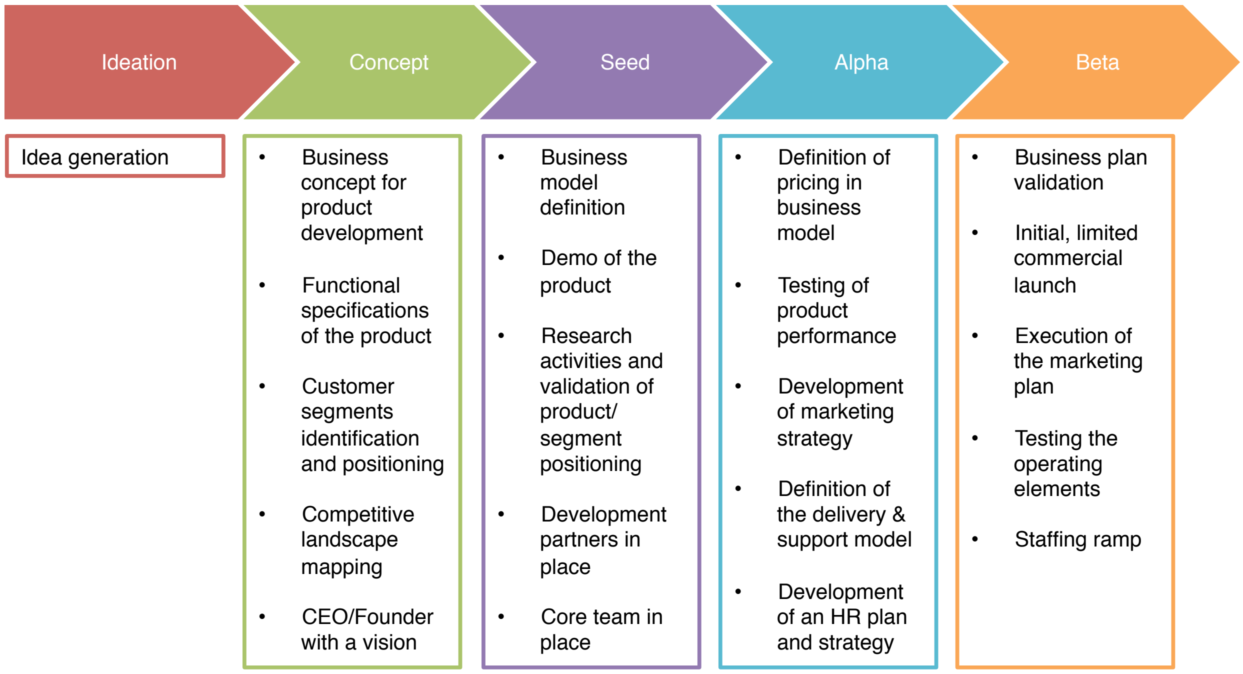

Figure 9. The Bell-Mason framework for the development of corporate ventures. Adapted from (Mason & Rohner, 2002).

Project Management Process

The Project Management Process (PMP) is a stage-gate process, which considers different phases of product development, each ending with a decision gate. At these gates, decisions are made on whether to move to the next stage or not. A schematic representation of this process is given in Figure 10.

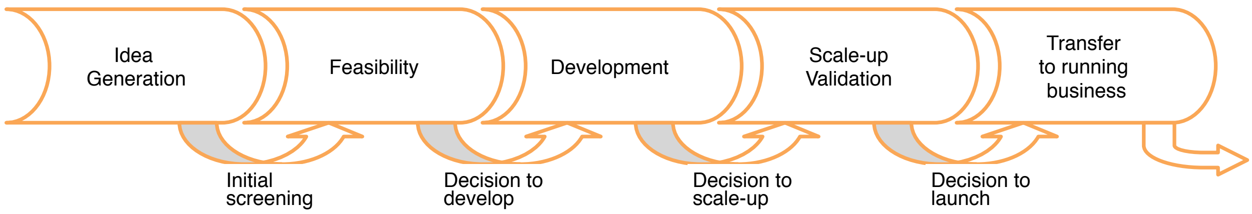

Figure 10. The Project Management Process Approach, as used at DSM. Adapted from DSM intranet.

The Idea Generation phase serves as an evaluation of the ideas that have been generated based on, for instance, observed market trends. An opportunity is identified, which is taken into the next phase: Business Feasibility. This stage is crucial for the progress through the remaining stages, as an inadequate analysis of the idea's feasibility can implicate unnecessary development costs for DSM. During the Feasibility phase, the full range of options is explored for an opportunity in terms of both market and technological features. All potential options need to be considered in equal amount and evaluated, which will result in a business case at the end of the phase.

With the establishment of a business case, the Development phase is entered after the decision has been made to continue with the project. This phase focuses on the assessment of the up-scalability of the option discussed in the business case. Moreover, the option is assessed on the fit with the contemporary business needs of DSM. If this is the case, the decision is made to move to the Scale-up and Validation phase, which serves to fully work out an implementation plan of the proposed activities in the business case. By the end of this phase, all elements need to be in place to execute the development plan of the project. If the decision is made to continue with the business case, the strategy of development is fully implemented into a running business.

The respondents have indicated that the phases of Idea Generation and Business Feasibility are considered as the fuzzy front end of new product development. Most debate is posed during the Feasibility phase, as the activities in this phase are least defined. Within the Innovation Center, efforts are made to structure this phase in order to gain consistency in the undertaken activities. However, this has not yielded a best practice thus far, especially in the case of disruptive innovations.

Conclusion

During the interviews, the need was named to integrate the 'venture thinking' with the 'new product development thinking', i.e. merging the principles of Bell-Mason with the PMP approach. Therefore, this will be used as one of the requirements of the structured fuzzy front end model. Moreover, the respondents have indicated that the key discussion within these models is finding the best practice to move through the Feasibility phase of the PMP approach. For this reason, the structuring of the fuzzy front end will focus on the Feasibility phase.

5. THE STRUCTURED FUZZY FRONT END MODEL

In this chapter the proposed model for structuring the fuzzy front end is presented, based on the interviews conducted with internal experts (see section 4.2 for the current decision-making process) and literature. First, the findings from the literature study on fuzzy front end models are presented, followed by indications for structuring the model derived from the interviews. Subsequently, the structured model will be assembled and presented. Finally, the assessment factors will be allocated to each phase of the model using the results from the panel study.

5.1 ASSEMBLY OF THE MODEL

Based on the models presented in section 3.4 and the decision-making aspects highlighted in chapter 4, a structured fuzzy front end model is yielded through the fusion of all these elements. The result of this fusion is presented in Figure 11. The elements on which this fusion is based, are listed below:

- Fusing the models proposed in section 3.4 yields a stage-gate model, which takes into account contextual factors of the organization, strategy and a sufficient amount of flexibility by integration of feedback loops between the phases.
- Implementation of decision-making roles in each phase based on the current decision-making process in the DSM Innovation Center.
- Coupling of the structured fuzzy front end model with the venturing model that was mentioned during the interviews: the Bell Mason model. By doing so, the corporate venture development within the Innovation Center is integrated with new product development, which provides more overview in the steps that need to be taken after the fuzzy front end has finished.

This section will discuss the activities undertaken in each phase and the main characteristics of the decision-making process taking place. A summary of these characteristics is provided in Table 10.

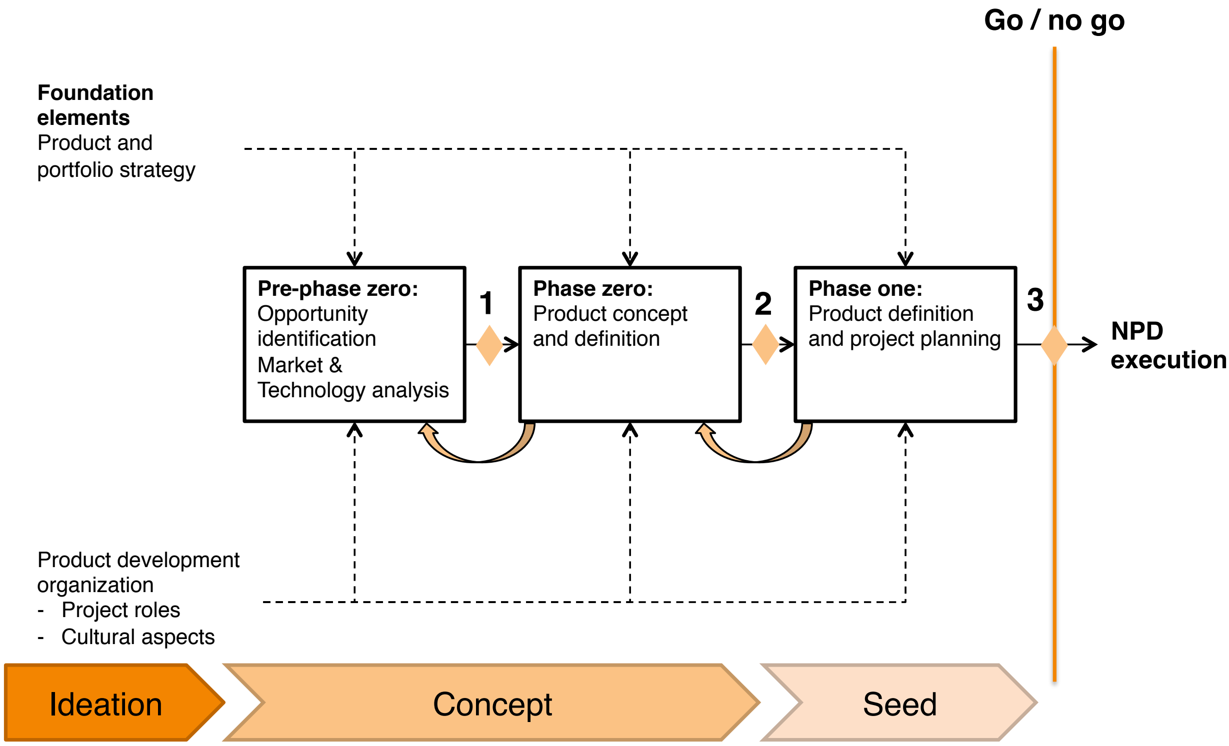

Figure 11. The structured fuzzy front end model.

5.1.1. Pre-Phase Zero

During the first phase of this fuzzy front end model, the activities undertaken have a strong qualitative nature, as it concerns an initial screening of an idea generated during the Ideation or Idea Generation phase. The idea formed in Idea Generation therefore serves as the input for pre-phase zero, which may come from outside or inside of the organization. Mostly, the ideas generated for disruptive innovations are the result of 'technology push' (source: internal communication).

The activities within this phase are two-fold. First of all, this phase serves as an idea-generating phase for development strategies that can be employed when moving into the development phase. In order to generate these ideas, an initial screening of the market and the technology at hand needs to be executed. The focus lies on identifying main market trends that are beneficial to the innovation and the existence of an intense customer need for a product as the idea generated. Second, an initial assessment is made on the fit with the strategy employed by DSM, which can be on any level of the organization: corporate level, business group level, portfolio level and project level. Also, an initial fit with DSM's competences is analyzed.

Table 10. The activities, deliverables, decisions bases and the decision-makers for each phase of the proposed model.

	Pre-phase zero	Phase zero	Phase one
Activities	• Idea formation on development • Trends & unmet need • Initial feasibility & fit • Varying input sources • Qualitative	• Concept & demo development • Cross-functional team • Product positioning in segments • Intermediate feasibility halfway • Quantitative	• Financials & planning for development • Scenario mapping • Strategy for development • Value chain mapping
Deliverable	Five- to ten-pager	Concept for product development strategy	Business case
Decision basis	• General market overview & technological characteristics • Gut feeling	• Detailed industry overview (market fit) • Company fit (strategy)	All factors worked out thoroughly
Decision-maker	Project owner	Project owner	Venture steering group

As this phase mostly entails a general screening of the idea, the project owner or the developer of the idea can make the decision to move to phase zero. However, the danger of doing so is that the project owner is biased towards his or her own project and wants this project to work. Thus, it is of great importance that this decision is approved by the VP of the Business Incubator, in the case of application on DSM. The deliverable on which this decision is based is a five- to ten-pager, where the findings from the initial market-. technology- and DSM-fit screening are reported and analyzed. The information presented is of a qualitative nature, which means that the rationality of the decision is limited. This emphasizes the role the VP needs to play: his intuition and experience will provide the necessary foundation for making the decision.

5.1.2. Phase Zero

In contrast to pre-phase zero, phase zero has more of a quantitative nature. The activities in this phase become more detailed, as the innovation needs to be positioned into the market segments that have been identified in pre-phase zero. The ultimate deliverable of this phase is a concept plan for the development strategy of the innovation. As the amount of information needed is quite extensive, at the beginning of the phase a cross-functional team is assembled to execute the project in order to represent different angles on the project. This may be employees from R&D, new business development, IP, regulatory, etcetera. Halfway through this phase, a feasibility study needs to be performed in order to determine whether the concept strategy needs to be formulated. If the project is not at all feasible based on the insights from the different parties, there is no need for strategy formulation.

The responsible decision-maker by the end of this phase is the project owner, but again, due to the biased vision this employee may have, the approval of the VP is very valuable. The project owner pitches the feasibility of the project as well as the concept strategy, after which the VP will express his approval of the decision to further develop or not.

5.1.3. PHASE ONE

The final phase of the model, phase one, considers the most detail of these phases. During this phase, the concept strategy for product development serves as the starting point, upon which the financial picture is drawn and the development itself is planned into detail. An important aspect of this phase is that risks and scenarios are mapped that are involved in the development of the innovation in order to formulate mitigation strategies, in other words scenario planning. These strategies are based on impact factor and the probability of the risk occurring in reality. By doing so, the project executer is forced to dive deep into the information needed, which reduces uncertainties in especially the technological sense, as it considers development strategies. Having multiple scenarios planned, the development phase is facilitated and the uncertainties in that process are also reduced. Moreover, the organization needs to be positioned into the value chain of the industry and the organization's role within this value chain determined.

In order to make development successful, phase one should also focus on the strategic considerations in development partners that need to be in place. Without the presence of development partners, a 'no go' decision will be given to proceed to the next phase.

This phase will be concluded with the presentation of the detailed business case including the strategy for development. The decision maker for the next phase is defined as the venture steering group, which includes the Innovation Council and the VP of the Business Incubator. In this case, the platform potential of the innovation will be one of the most important criteria, as the development phase will potentially entail the set-up of a corporate venture.

5.2 ASSESSMENT FACTOR ALLOCATION

The structured fuzzy front end model developed in the previous section has a defined structure in terms of the decision-making process underlying the model and the activities taking place in each phase. In Chapter 3, a list of factors was provided that was of importance when considering the assessment of the feasibility of innovations during the fuzzy front end. In order to determine in which phase the factors are important and the degree of importance of each factor, a panel assembled these factors for each phase of the model. This chapter will explain the methodology behind the panel technique used, as well as the results from this methodology.

5.2.1. METHODOLOGY

In order to further structure the fuzzy front end model presented in section 5.2, the factors presented in Chapter 3 need to be assigned to each phase of the model. The interviews with internal experts have shown that not all factors may be important in each phase of the model, which suggested that the factors' importance for each stage may vary. Also, the interviewees have indicated that at early phases, less or less detailed information is needed to proceed to the next step than is the case in later stages of the fuzzy front end. Based on this information, the following three assumptions are made:

1. The factors that are relevant for each of the phases vary when moving through the model, meaning that different factors are relevant in different phases.
2. The factors that are relevant for one phase will still be relevant in the subsequent phase, as the information needs to be updated, reviewed and validated.
3. The importance of these factors vary for each of the phases when moving through the model, meaning that the degree of importance of each factor varies per phase.

The interviews have shown that different views were obtained considering the types of information that was needed during the fuzzy front end of new product development. This implicates that there is a strong need for a unified protocol considering the factors needed in each phase. Therefore, based on this information and the above-mentioned assumptions, a method was needed that could generate a unified result from the internal experts regarding the needed factors for each phase and their importance. In order to derive whether the factors from early stages are still relevant in late stages of the fuzzy front end, the method needed to allow multiple rounds to be executed. By doing so, the factors found relevant for the first phase could be tested for their relevancy in the second phase; the same holds for the procedure for the third phase.

The chosen method to conduct this research was a panel study, due to several reasons. First of all, it allows for multiple rounds to be performed with a panel of experts with a specific background, which is needed in order to provide the required expertise. Second, after each round, the results are gathered and combined by a central coordinator, which then may serve as the input for the subsequent round. The following sections will provide more information on the used technique and present the design for executing the research.

Panel Study

A panel study is a longitudinal study performed with a group of individuals around a certain topic (Sekaran & Bougie, 2013). The duration of the panel study depends on the research topic: it may even take years to complete. The main characteristic of a panel study is that a panel provides input into a research problem more than once. However, a panel study utilizes a random selection of individuals, which is not the case in this research. The characteristics of the research undertaken are the following:

- A group of internal experts is carefully selected to participate in the panel in order to ensure the quality of the results;
- The panel members are not able to attend plenary discussions on one location due to geographical distribution;
- Anonymity of the panel members is needed, as the members' positions vary across the organization. The members need to be able to give their opinion, without any pressure to comply to the opinion of their seniors or superiors;

- The rounds of the study are based on the different phases of the structured fuzzy front end model, meaning that the content of each round varies;
- Surveys are distributed in each round of the study. The results from one round are used as input for the subsequent round.

The characteristics stated above resemble some of the characteristics of the Delphi technique. This technique revolves around a panel of carefully selected experts of a similar background, who will answer questionnaires on a specific topic. Normally, this topic would be the same in each round, as the ultimate goal of the Delphi technique is to reach a consensus among the panel members through multiple rounds (Brill, Bishop, & Walker, 2006). Each round used in this research will each revolve around one of the phases of the structured fuzzy front end model, meaning that the questionnaires are not based on the same topic. Moreover, the ultimate goal of this research is to provide a list of most important factors for each round together with their relative importance, which does not need a consensus, but a mere voting. Based on the results, an assessment can be made on the extent to which a consensus has been reached.

Linstone and Turoff (2002, p.4) have argued that several propositions exist that may lead to researchers resorting to the Delphi technique, of which one or more needs to be complied to (Linstone & Turoff, 2002). For instance, if the information sought is of a subjective nature, this technique proves to be more effective than any analytical tool. Moreover, face-to-face communication is difficult due to geographic distribution. These two aspects are applicable to the research conducted in this thesis. First of all, subjective judgments are needed in order for each panel member to channel their personal experience in the topic; it is the nuances or differences in the results that is sought after. Moreover, the experts within the researched topic are distributed geographically, both nationally and internationally. Due to time and costs concerns, it is difficult to organize multiple face-to-face interactions.

Putting these aspects together, the chosen method to investigate the relevant factors per phase of the model as well as the relative importance is the Delphi technique, while applying minor changes to this method. These changes are:

- No explicit consensus is sought after at each round. It is the difference in opinions from the panel member that is of interest, assuming that this difference exists;
- Each round will revolve around a different phase of the fuzzy front end model instead of on the same phase for all rounds.

The next section will elaborate on the research design used in order to obtain the desired data.

Research Design

The panel study is designed in such a way, that the opinion of the experts in the panel is reflected and converged. The study is performed in three rounds; one round for each phase of the structured fuzzy front end model. The following sections will explain the requirements for the panel members, the contents of the rounds and the communication method towards the panel.

MINIMUM REQUIREMENTS OF THE PANEL

In order to ensure the quality of the answers provided during the panel study, this study is executed with internal experts within the organization that comply to the following qualifications:

- Minimum of 5 years' experience in innovation management at DSM;
- Knowledge of disruptive innovation processes at DSM in order to create the correct context for the study;
- Current involvement in the decision-making process of project selection in portfolio management or in best practices within this field. This role may be supporting or may have decision power;
- At least involved in a position as (or similar to) a project director or innovation manager.

According to Delbecq et al., the sample size for the Delphi Technique is variable, depending on the selection specificity of the panel. If the panel includes participants from similar backgrounds and experience, a sample size of 10 to 15 is sufficient, while more is required when participants from different backgrounds are required. In this case, the selected experts all have similar backgrounds and experience (Delbecq et al., 1975). Therefore, the aim is to have 15 members in the panel. A total of 24 members was asked in order to ensure that a minimum of 15 panel members would be involved in each round of the study.

CONTENTS OF THE ROUNDS IN THE PANEL STUDY

The panel will be executed in three rounds: one round per step as described by the proposed fuzzy front end model. Prior to these rounds, the participants will be notified about the procedure and a short introduction will be provided on the model itself. This introduction is kept short in order to only provide the necessary information to understand the model, but not create any bias towards the importance of certain assessment factors. The procedure per round is explained in the following sections.

Round 1

During the first round, the first step of the fuzzy front end model is highlighted. The panel will receive a list of all the assessment factors found in literature. From this list, each participant is asked to which factors are important in this first step. After the panel has provided its lists, the data will be merged into one top 10 of assessment factors.

Round 2

The second round will focus on the second step of the model. The panel will receive two types of information: the top 10 that resulted from the first round and the remaining assessment factors that were not in the top 10. This time, the panel will be asked three questions:

1. Indicate the importance of the top 10 factors in the first step of the fuzzy front end model.
2. Are the factors of the top 10 from the first round still relevant in the second step? Indicate their importance for this step.
3. Highlight 1 to 5 more factors that are relevant in the second step of the model.

The panel members are able to indicate the importance of each factor by a predetermined categorical scale, consisting of four measures:

- No importance
- Slight importance
- Medium importance
- High importance

The scales are associated with quantitative scores, which will yield an average score by the end of the round. In order to highlight the differences between the assessment factors (or lack thereof), the scores used for the ranking of factors will range from 0 to 4. The following scoring mechanism is installed:

- No importance: 0
- Slight importance: 2
- Medium importance: 3
- High importance: 4

By checking the importance of the top 10 factors in the second step compared to the first step, insight is gained into the difference between the phases. This difference may be based on the type of information needed, or merely the level of detail between the phases. Moreover, it is assumed that in each step of the process, the amount of needed information increases. Therefore, the panel is asked to name five more assessment factors, that were excluded from the top 10 from round 1.

The lists obtained from round 2 may range from top 5 to top 15 lists, depending on the relevance of the assessment factors highlighted in the first step.

Round 3

For the third round, the same procedure holds as for round 2, though the results from round 2 will be sent to the panel.

COMMUNICATION TO THE PANEL

The panel will be officially contacted four times during the procedure, apart from asking the participants personally to join the panel. The first time, an e-mail will be sent to each panel member (anonymously) explaining the procedure and outlining the dates on which the rounds will be executed. A confirmation is asked of the panel members on whether they would still be available to execute the study before the indicated times.

The second, third and fourth time, the web link to the online survey is sent to each panel member, along with the date and time when the survey needs to be completed. One reminder is sent to panel members that have not completed the survey before the deadline. The results of each rounds are presented in the subsequent round by means of the survey itself.

5.2.2. General observations & Factor allocation

Before the panel study was executed, the panel members were asked to participate. A total of 15 members have explicitly committed to participation in the survey, indicating that they would be able to complete the surveys before the indicated deadlines. The survey was still sent to others, who were asked for their participation through digital correspondence, but who did not send a response. For each round, the following amount of panel members have completed the survey consistently:

- Round 1: 14 respondents, and 1 past the deadline (which could not be used)
- Round 2: 15 respondents
- Round 3: 15 respondents

The qualifications of each respondent in each round are demonstrated in Table 1. All respondents qualify to the position as (or similar to) project director or innovation manager. A background check was performed in order to ensure that these panel members have sufficient knowledge of disruptive innovation processes: all panel members are in various degrees involved in disruptive innovations. Some are involved in these innovations on a daily basis, while others participate in councils or meetings where best practices within disruptive innovation management are discussed. Moreover, all respondents have a minimum of 5 years' experience in innovation management. Therefore, one can conclude that the composition of the panel will yield trustworthy results when taking the earlier-stated requirements into account.

After completion of the surveys, the panel members were asked for feedback on the surveys. Respondent number 3 has answered that he missed the project management aspect of innovation management in the survey. As this aspect was already indicated as inherent to the model, it was still left out of the survey. Other responses were that the surveys were very clear, interesting and easy to comprehend and complete.

For each phase of the structured fuzzy front end model, factors were identified after each round that were voted on by the panel members. This section will present the factors that were deemed as most important by the panel members in each phase.

Round 1: Pre-Phase Zero

During the first round, the panel members were asked to select 10 assessment factors that were relevant for the first phase of the fuzzy front end model: pre-phase zero. The panel members were presented with all assessment factors found in literature (see chapter Theoretical Background). All the responses were gathered and a top 10 of most relevant factors was composed based on the number of votes on each factors. The distribution of the votes over the factors is displayed in Figure 12.

The factor 'customer need intensity' was the only factor that showed complete consensus among the 14 respondents: it was selected by all respondents. This factor is closely followed by the factors 'strategic fit' and 'customer landscape' with 12 and 11 votes, respectively. From these factors onwards, the opinions appear to be more scattered: multiple factors have the same amount of votes and the differences between the amount of votes are smaller. Based on the scores alone, a top 10 of factors is identified:

1. Customer need intensity
2. Strategic fit
3. Customer landscape
4. Competitive intensity
5. IP landscape
6. Competences fit
7. Attainable market size
8. Time to market
9. Technology newness
10. Market growth

Table 11. The qualifications of the panel members who consistently completed the surveys.

Resp. #	Position at DSM	Years of experience
1	Project Director	5
2	Project Director	21
3	Business Manager	28
4	Program Manager	16
5	Innovation Manager	6
6	Vice President	30
7	M&S Platform Manager	20
8	Project Director	>15
9	Business Analyst Incubator	25
10	Ideation Manager	5
11	New Business Development Manager	9
12	Innovation Manager	30
13	Ideation Manager	25
14	Innovation Process Manager	15
15	Project Director	17

The factor ‘attainable market size’ had obtained more votes than ‘addressable market size’ (9 compared to 5 votes, respectively). The addressable market size considers the size of the market based on the application of the innovation, while the attainable market size is defined as the portion of the addressable market size that may be taken by the company. During pre-phase zero insufficient knowledge exists to determine the attainable market size, thus one would state that the addressable market size is more relevant in this early phase. The panel members that have voted for this factor were asked for clarification of their definition of this factor: it became clear that the definitions for these factors were confused with one another. Therefore, the panel members most likely meant to indicate ‘addressable market size’ for this phase.

Based on the amount of votes alone, an initial ranking of the factors may be obtained. The results of the obtained rank will be discussed further in comparison with the data for the importance of each factor in section 5.2.3.

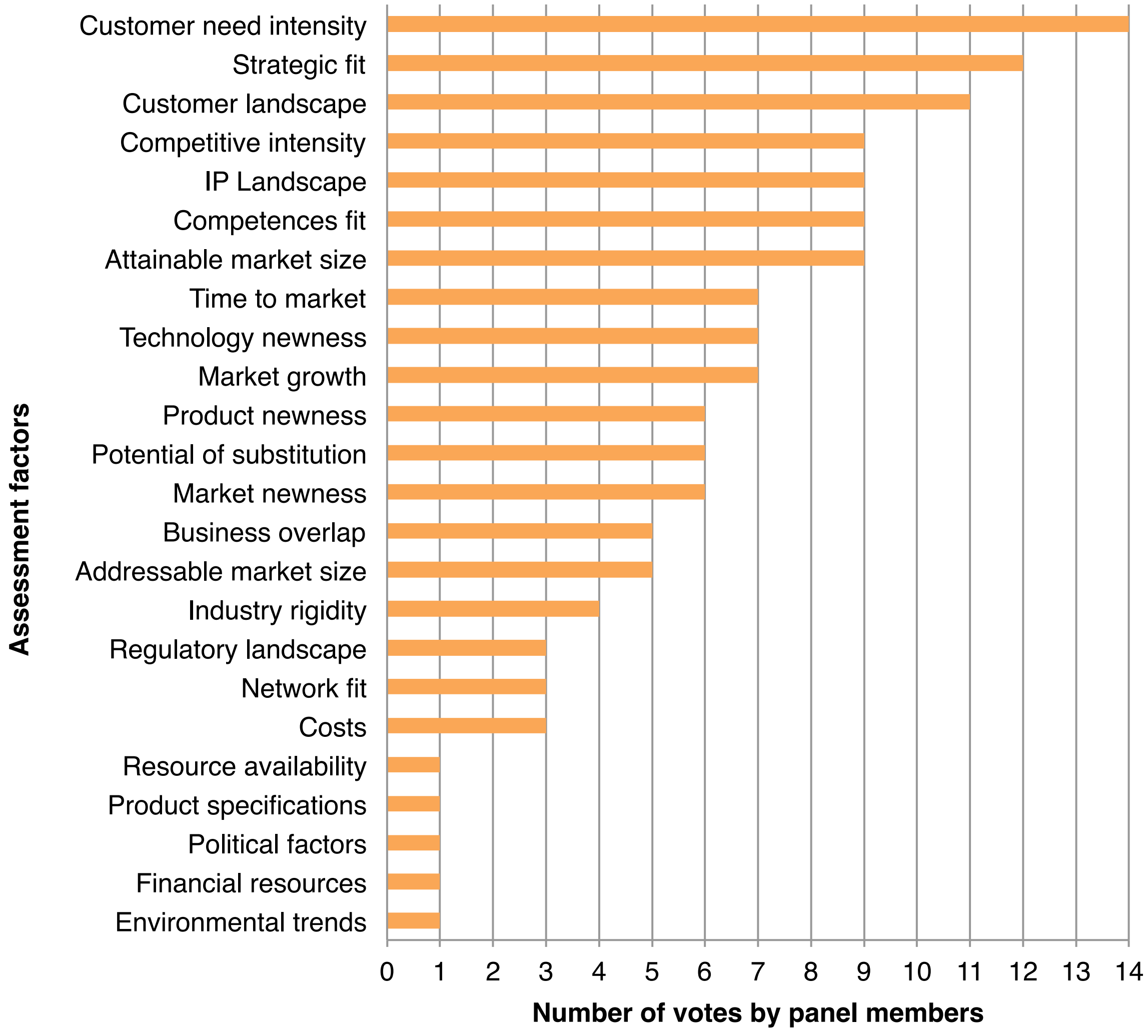

Figure 12. The distribution of votes for each assessment factor in pre-phase zero of the fuzzy front end model.

Round 2: Phase zero

Earlier, the assumption was made that while moving through the fuzzy front end model, more factors become relevant in the phases, as the information obtained in each phase increases in detail. Therefore, during the second round, the panel members were asked to select a minimum of 1, but a maximum of 5 additional factors that are relevant to consider in phase zero of the fuzzy front end model. The factors that were included in the top 10 were not included in the list the panel members could choose from. Almost all panel members have indicated 5 additional factors: an amount of 3 out of a total 15 members have selected less than 5 factors (1, 3 and 4). The distribution of the votes of this round are presented in Figure 13.

In contrast to the results obtained in round 1, the panel members' opinions varied significantly: the largest number of votes on one factor was 7 out of 15, which is less than 50%. Therefore, no clear 'winners' can be distinguished in these factors, meaning that a top 5 list is not reliable. However, the distribution pattern of the votes is comparable with the results obtained during round 1: the top 4 of relevant factors for round 2 were closely behind the top 10 in round 1.

For the sake of the continuity of the panel study, the factors with over 5 votes were selected to feature as additional factors, which are:

1. Addressable market size
2. Market newness
3. Potential of substitution
4. Industry rigidity

In order to obtain a full image of the ranking of these factors, the results of the importance of these factors are needed. These will be discussed in section 5.3.3, along with the comparison of these results.

Round 3: Phase One

The same procedure was employed for round 3, while taking into account the factors that were not featured in the top 4 of relevant factors for phase zero. The same amount of additional factors was asked to be selected (minimum of 1 and maximum of 5). The distribution of the votes is presented in Figure 14.

The panel members seem to agree more than was the case in round 2: the largest number of votes obtained for one factor here is 12 out of a total 15. A clear top 5 of these factors may be derived:

1. Resource availability
2. Costs
3. Product specifications
4. Financial resources
5. Market share

When comparing the vote distribution of round 3 with the previous rounds, the factor 'resource availability' generated the most votes in the third round, while in the previous rounds this factor was barely indicated as relevant. However, development costs and financial resources of the company have become increasingly more important throughout the rounds. This implicates that these factors are most relevant when the innovative product becomes more defined and a business case needs to be formulated. The same hold for the specifications of the product at hand: the more details are needed, the more focus lies on the performance of the product related to the targeted market segments.

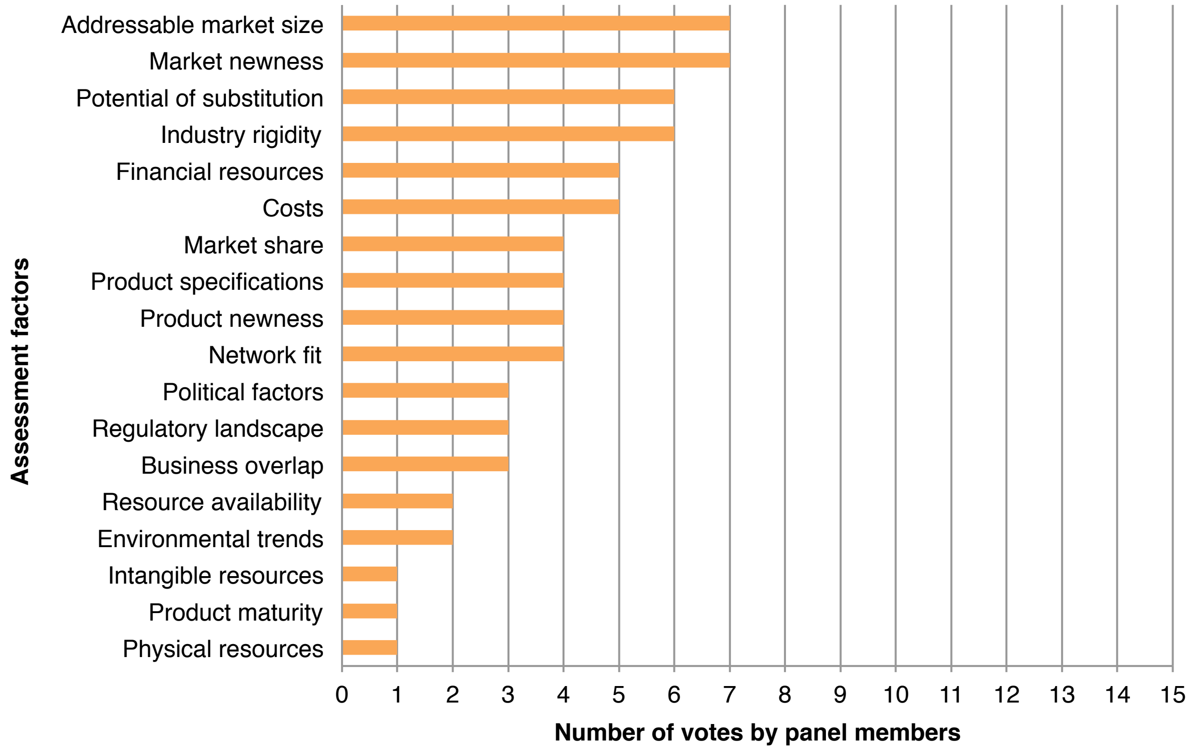

Figure 13. The distribution of votes for each assessment factor in phase zero of the fuzzy front end model.

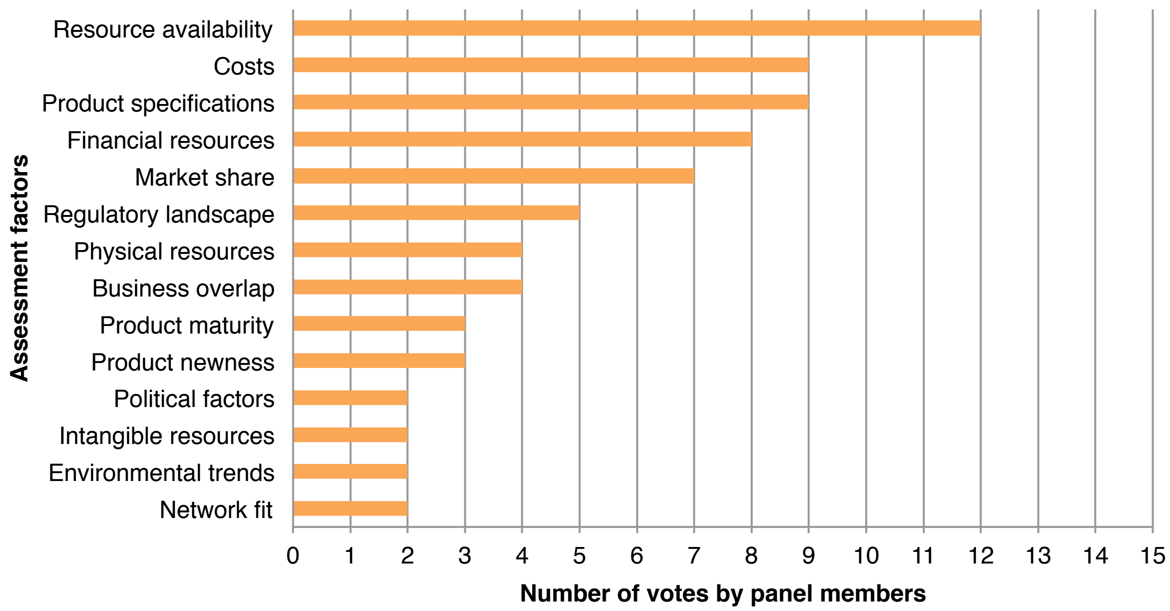

Figure 14. The distribution of votes for each assessment factor in phase one of the fuzzy front end model.

Discussion

In the three rounds, insights were gained into the most relevant factors that need to be considered when moving through the fuzzy front end. Based on the chosen factors by the panel members, a distribution may be assembled per phase of the model regarding the categories named in the factor category matrix: internal & external market factors and internal & external technological factors. The positioning of the selected factors for each phase in the categories is presented in Figure 15.

During pre-phase zero of the fuzzy front end model, the external market factors are most important considered to the other factor categories. This phase centers around an initial market and technological analysis, focusing on providing a broad outline of the innovation and its possibilities. External market factors will provide the most information in that stage on whether the innovation is feasible, as there is limited technological knowledge at that stage of product development. Therefore, it is to be expected that initially, the external environment of the company will have most focus in such studies. Interestingly, merely one more external market factor is considered from phase zero onwards; the selection is not expanded in phase one (Figure 15).

When considering the internal market factors, one can clearly distinguish an increase of factors selected when moving through the phases of the model (Figure 15). It appears that after the assessment of the market itself, the company needs to focus on positioning itself in the market by measuring its competences and resources regarding the innovation at hand. As this measurement depends on the nature of the innovation, the technological factors show a slight increase in selected assessment factors. The technological factors consider more detailed information than market factors, which is in line with the assumption that the amount of detail in the model increases when moving through the phases.

In order to validate the degree of importance of each factor in each phase, the scores given to each factor during the different rounds is used as a comparison. The scores will not only provide a clue on the weight of each factor in each phase of the fuzzy front end model, but also a comparison to the amount of votes on the factors and the scores designated to the factors. The scores obtained for all factors are discussed in section 5.2.3.

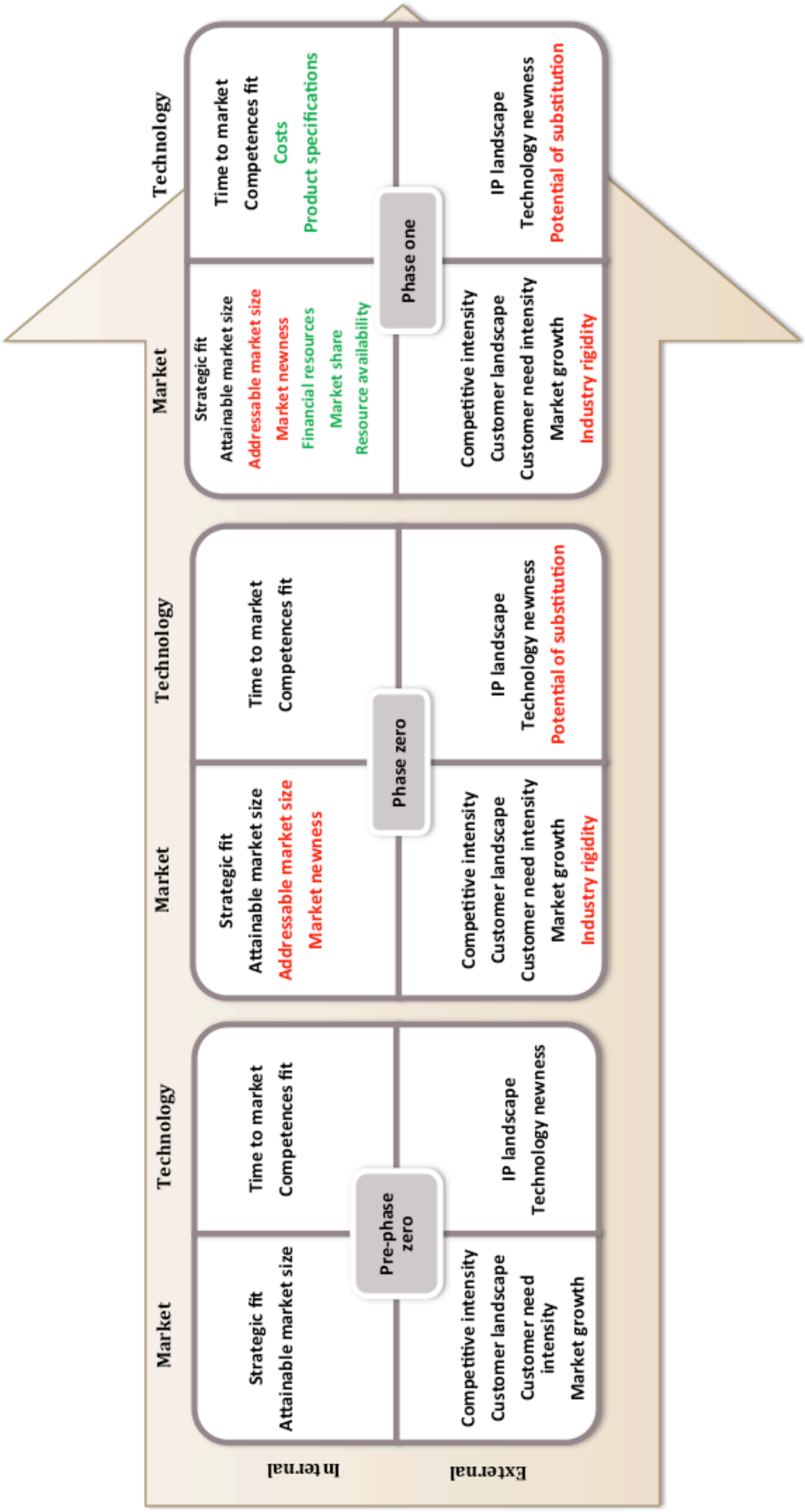

Figure 15. Positioning of the factors in the categories for each phase of the fuzzy front end model. Additional factors for phase zero are indicated in orange; additional factors for phase one are indicated in green.

5.2.3. THE IMPORTANCE OF ASSESSMENT FACTORS IN EACH PHASE

After assembling the lists of most important factors for each phase, the panel members were asked to indicate the degree of importance to each factor in every phase. This section will present the scores obtained for each factor, discussed per phase of the model.

ROUND 1: PRE-PHASE ZERO

Based on the top 10 of assessment factors assembled in the first round, the panel members were asked to indicate the degree of importance of each factor in the first phase of the fuzzy front end model (pre-phase zero). The average scores were derived from the panel's responses and presented in Figure 16. In order to gain insight into the reliability of these average scores, the standard deviation of the data set for each factor was determined and plotted as error bars.

The majority of the average scores are located at approximately 3, indicating a medium importance. Four factors show higher importance: customer need intensity, strategic fit, competences fit and attainable market size. When comparing these scores with the amount of votes obtained, one concludes that customer need intensity scores highest in both scenarios. Strategic fit is considered as first runner-up in both cases. The amount of votes indicated that the second runner-up was customer landscape, which is not the case with the average importance obtained (Figure 16). Instead, competences fit and attainable market size appeared to be more important. Both factors scored the same in both amount of votes and the average importance score.

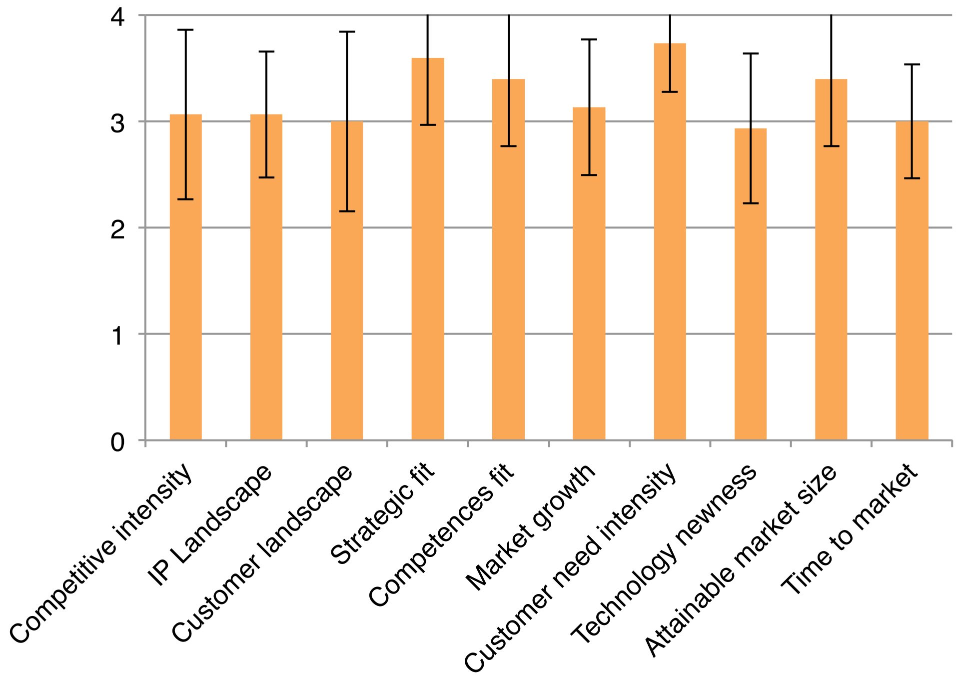

Figure 16. The average scores of each top 10 assessment factor in pre-phase zero of the fuzzy front end model. The error bars represent the standard deviation of the data set for each factor.

Even though the average scores provide an indication of differences between the factors, the standard deviations suggest otherwise (Figure 16). The spread of the answers provided by the panel is large, meaning that the opinions of the panel member vary largely. Therefore, the differences between the factors cannot be concluded to be significant.

ROUND 2: PHASE ZERO

The top 10 assessment factors from pre-phase zero together with the 4 additional factors from phase zero were assessed together on their degree of importance in this phase. The average scores given by the panel is displayed in Figure 17. As was the case for pre-phase zero (Figure 16), the differences between the average scores obtained for the factors mostly range between 3 and 4, with the exception of the factor 'industry rigidity'. This factor had the least votes in round 2, which is thus reflected in its degree of importance.

The addressable market size is scored as one of the most important factors to consider in phase zero. It appears to be slightly more important than the attainable market size, which obtained more votes than the addressable market size did in the first round. The mix-up of definitions with the panel members still existed during this round, which may be the reason for scattered opinion in the scoring.

The spread of the scores given by the panel members indicates the same conclusion as was drawn for the first round: the standard deviations of the averages are thus large, that the differences between the average scores are insignificant. The scores given by the panel members indicate a disagreement in the importance of each factor.

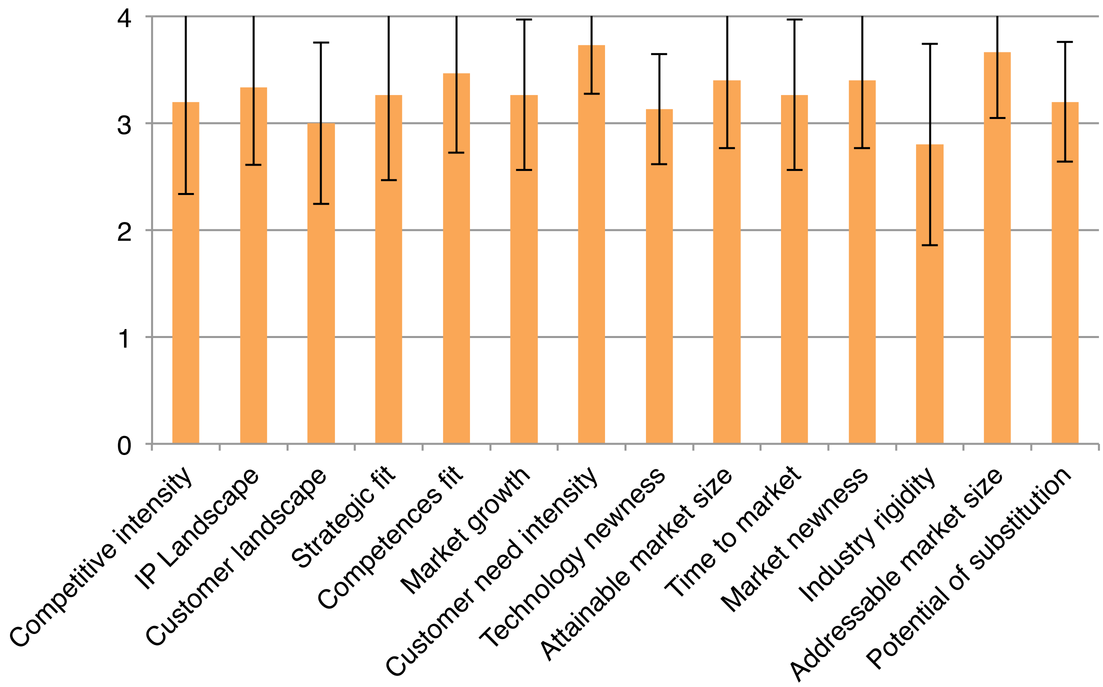

Figure 17. The average scores of each assessment factor in phase zero of the fuzzy front end model. The error bars represent the standard deviation of the data set for each factor.

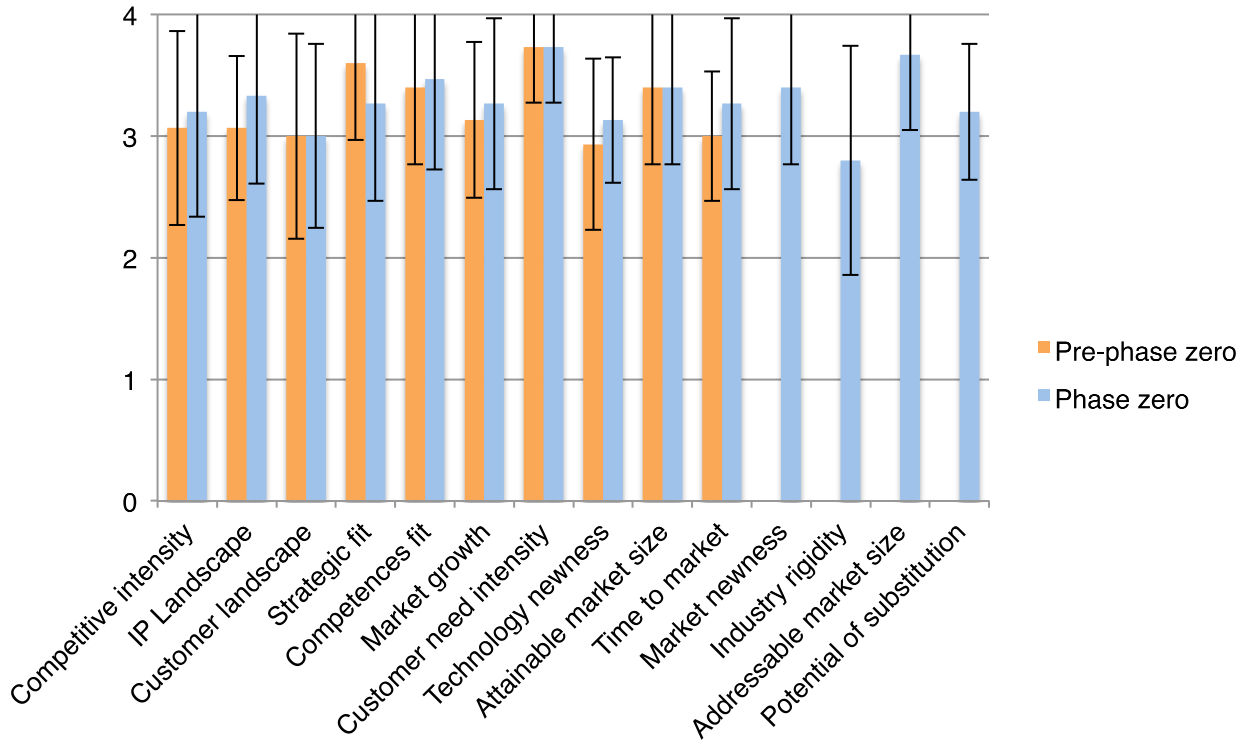

Figure 18. The average scores of the assessment factors of pre-phase zero and phase zero of the fuzzy front end model. The error bars represent the standard deviation of the data set for each factor.

When comparing the degree of importance of the factors for the two phases (Figure 18), the error bars still cause the same conclusion to be drawn: no conclusions can be drawn considering the differences between the phases. Again, the opinions of the panel members vary greatly. However, a few observations are still made:

- The importance of the factor 'IP landscape' increases in importance when moving from pre-phase zero to phase zero. While advancing through the model, more information becomes available on the innovation to be assessed, meaning that more specifics on the involved technology become clear. The IP landscape will need more attention in that case, as the innovation may already be filed as intellectual property. This needs to be reviewed regularly.
- The importance of the factor 'strategic fit' becomes less important in phase zero. Apparently, this factor needs less attention in later phases of the model, as this information is typically assessed in the earliest stages of development. Once the strategic fit of the innovation is confirmed, it is not probable that new information comes to light in a later stage. This factor still remains important as a benchmark.
- The differences between the remaining factors is small or inexistent, meaning that their respective importance remains the same when moving to a later phase.

Round 3: Phase One

The degree of importance of the assessment factors was also assessed for the third phase of the fuzzy front end model: phase one. This phase is the final phase before moving to product development, meaning that the innovation needs to be defined in a business case. The importance of all factors in this phase are presented in Figure 19. The differences between the average scores are more widely spread than was the case in the previous rounds. However, as the standard deviations (or spread of the scores) are very large, no significant conclusion may be drawn from these results.

When comparing the results from all three rounds (Figure 20), in some cases a trend is observed in the average score while moving from one phase to the next. The factors showing a trend are:

- IP landscape: throughout the model, this factor gains more importance. As more knowledge becomes available on the innovation itself, the team executing the studies becomes more familiar with its characteristics. The IP searches are therefore more detailed and specific. The feasibility of the innovation depends on whether the intellectual property on (one of) its features has already been filed as intellectual property.
- Strategic fit: in the first phase, this factor is most important. In subsequent phases, it has lost importance, as the focus shifts to the specifics of the innovation and its market landscape, instead of its alignment with the company's strategy. A regular update and review of the innovation's fit is still necessary, which explains that the importance of the strategic fit is still high in phase zero and phase one.
- Customer landscape: in pre-phase zero and phase zero, the customer landscape had comparable importance. Its importance increased for phase one. As the definition of a product development strategy is most important in phase one, the customer landscape needs to be mapped fully. This includes having potential customers installed and in some cases, having joint development agreements in place.

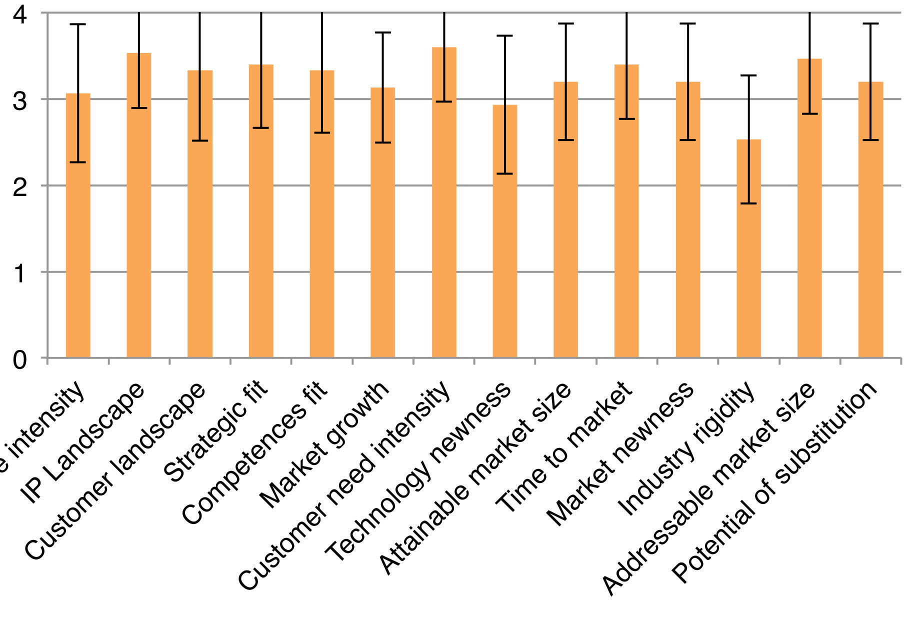

Figure 19. The average scores of each assessment factor in phase one of the fuzzy front end model. The error bars represent the standard deviation of the data set for each factor.

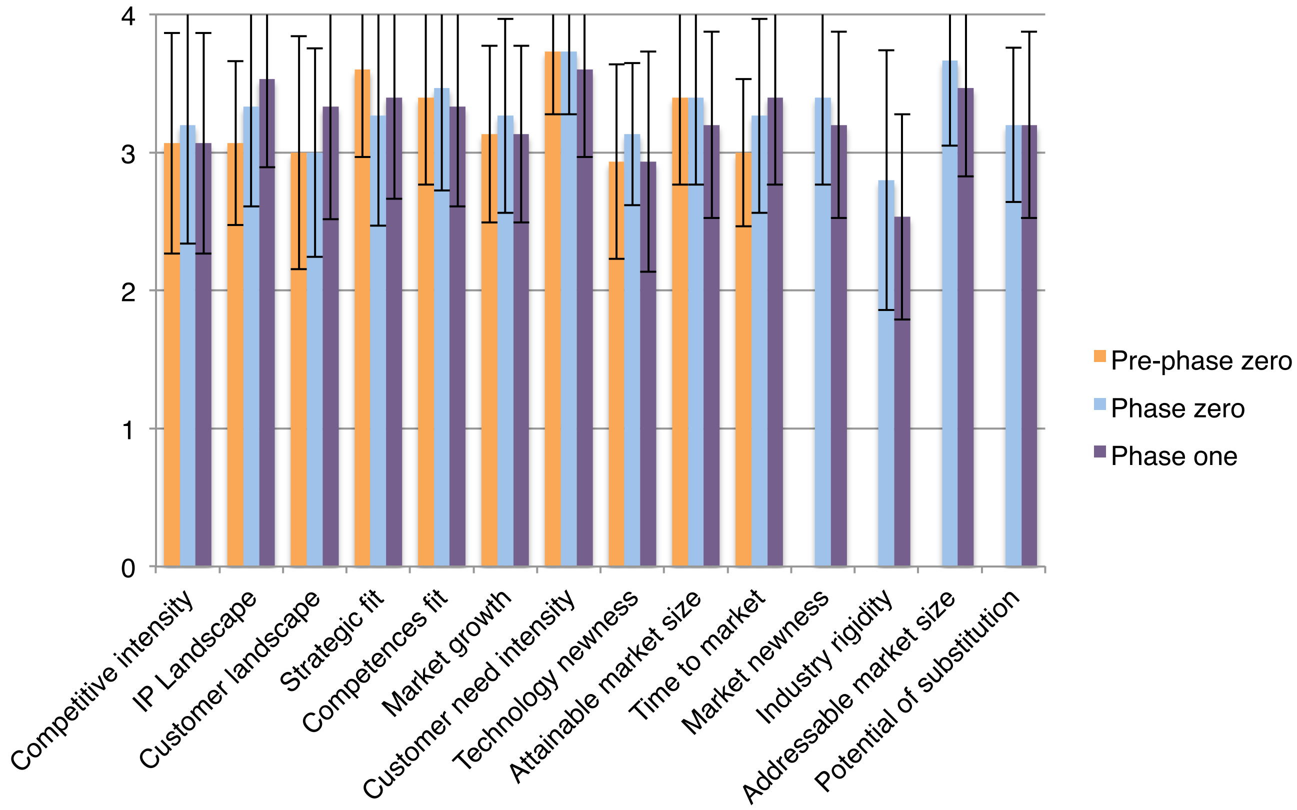

Figure 20. The average scores of the assessment factors of pre-phase zero, phase zero and phase one of the fuzzy front end model. The error bars represent the standard deviation of the data set for each factor.

- Time to market: an increase of importance is observed for this factor when moving through the phases. As was the case for IP landscape, more information is available on the innovation when approaching the end of the model, meaning that the technological aspects become more detailed. The time to market is expected to increase in importance, due to the increased availability of knowledge on product performance and characteristics.

As the spread (i.e. the error bars) in the panel responses is very large, still no definite conclusions can be drawn from the observed trends. In order to assess which scores are most probable to reflect the common opinion, an extension of the panel is required, yielding more results.

Discussion

As became clear from the average scores in each round, the panel members did not agree completely on most factors, resulting in a large variance in the scores provided. Due to the large spread, no definite conclusions can be drawn on the significance of the differences or trends observed. More insight on the common opinion of the panel can be gained by taking into account the scores that are given most for each factor in each phase: in other words, the mode of each factor data set is derived and plotted along with the scores. The modes can give an indication in the way that the average scores reflect the scores that were given by most panel members.

For the first round (pre-phase zero), the modes correspond to the average scores for the factors 'competitive intensity', 'IP landscape', 'market growth', 'technology newness' and 'time to market' (Figure 21). For these factors, the average scores resemble the common opinion of the panel members. The appearance of large error bars is therefore mainly due to the diversity of the given scores.

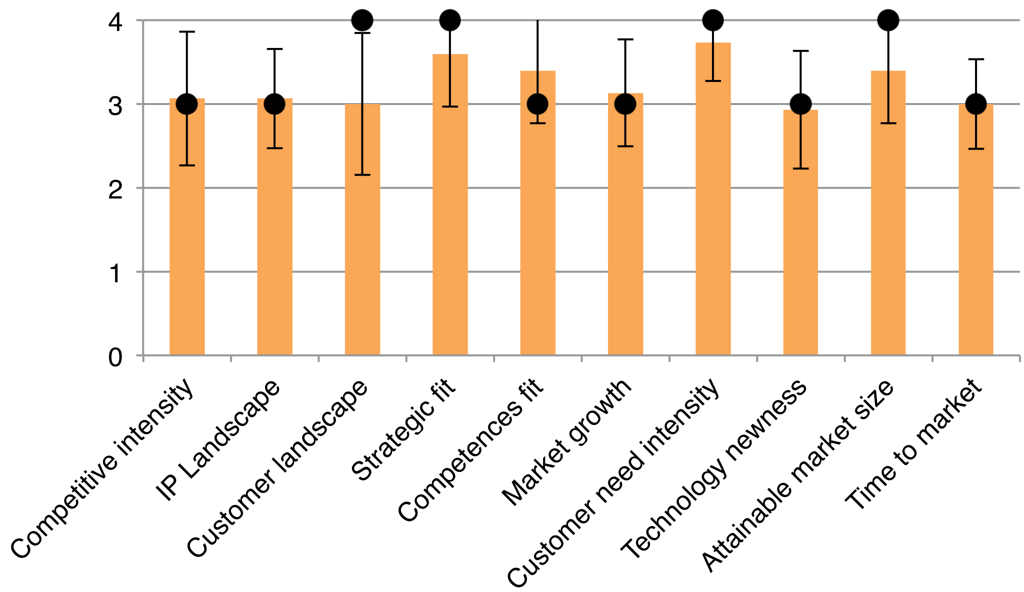

Figure 21. The average scores and modes of each assessment factor in pre-phase zero of the fuzzy front end model. The error bars represent the standard deviation of the data set for each factor. The Black dots represent the modes.

The factor 'competences fit' shows a larger average score than the common opinion. This indicates that the amount of votes for either 'medium importance' (i.e. score of 3) or 'high importance' (i.e. score of 4) is almost tied, with a slightly larger number of votes for 'medium importance'. Other factors, such as 'strategic fit' and 'attainable market size', have had most panel members voted as highly important than other degrees of importance. Again, the spread of the scores causes the average scores to be lower than the opinion of the majority of the panel members. The customer landscape factor is an extreme case of this spread: most panel members voted for this factor to be highly important, while some members have scored this with a low degree of importance. The importance of the factors in pre-phase zero are therefore stated to be valid for the cases where the modes correspond to the average scores, regardless of the large standard deviations. The factors for which this is not the case, the error bars provide proof that the opinions are thus divided, that no conclusion can be derived on the significance on the average scores.

In the case of the second round (i.e. phase zero), the differences between the average scores and the modes become more apparent than in the first round, indicating significant disagreement between the panel members (Figure 22). This corresponds to the pattern of disagreement in the selection of most relevant factors, which was presented in Figure 13. According to the majority of the panel members, the following factors are more important than the average scores depict:

- Competitive intensity
- IP landscape
- Strategic fit
- Competences fit
- Attainable market size
- Market newness

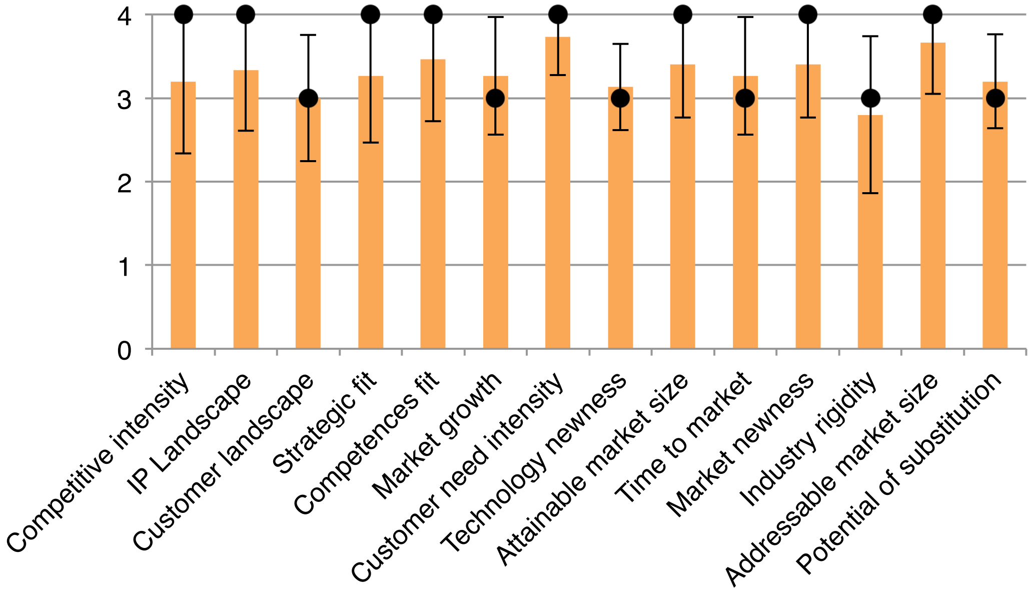

Figure 22. The average scores and modes of each assessment factor in phase zero of the fuzzy front end model. The error bars represent the standard deviation of the data set for each factor. The black dots represent the modes.

Interestingly, the additional factors that were chosen during the second round as being relevant for phase zero, have achieved more consensus in the scoring in their importance than in the voting on their relevance: the modes of the additional factors correspond to the average importance scores, except for 'market newness'. The most disagreement is found in the factors that were found relevant in the first round (i.e. pre-phase zero). The assumption that the factors from previous rounds are still considered in subsequent rounds is therefore up for discussion. However, the height of the scores indicates that the panel members generally agree that the displayed factors are indeed important.

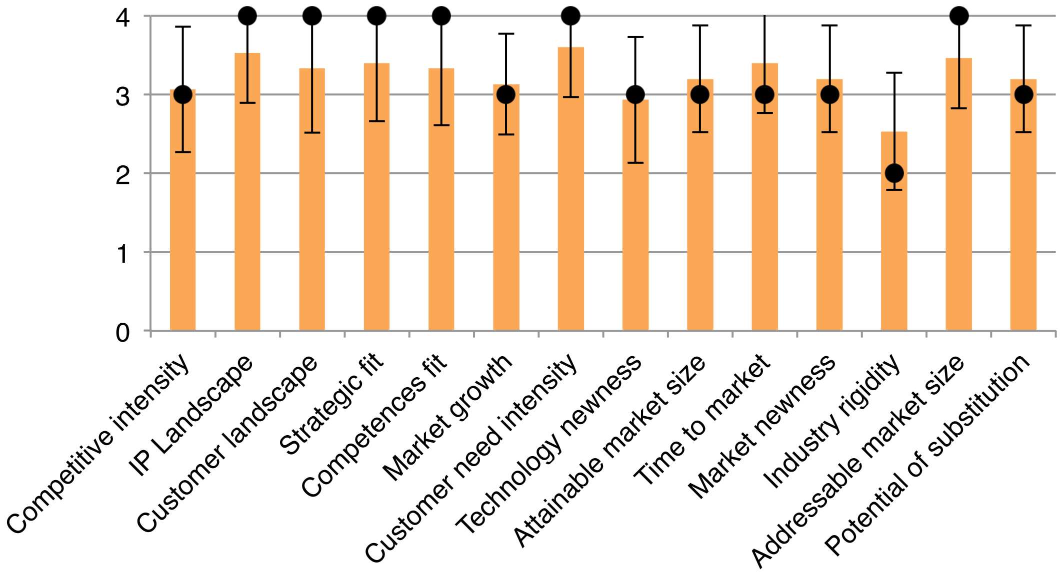

Figure 23. The average scores and modes of each assessment factor in phase one of the fuzzy front end model. The error bars represent the standard deviation of the data set for each factor. The black dots represent the modes.

Similar observations are made for the third round (i.e. phase one), as presented in Figure 23. The average scores of the factors 'competitive intensity', 'market growth', 'technology newness', 'attainable market size', 'market newness' and 'potential of substitution' resemble the opinion of the majority of the panel, as the modes correspond to these scores. Furthermore, large differences in opinions are observed for 'IP landscape', 'customer landscape', 'strategic fit', 'competences fit' and 'addressable market size'. In order to reflect on the relevance of the differences between the importance of each factor or lack thereof during all three phases, the modes and average scores of each factor for all phases are compared (Table 12). The factor 'technology newness' is the only factor that shows correspondence between the average scores and modes in all three phases, which means that the average scores reflect the opinion of the majority of the panel members. The same conclusion is drawn for the 'potential of substitution'. In both cases, no difference is observed in the degree of importance when moving through the phases. In the case of slight correspondence, the factors 'competitive intensity', 'market growth', 'customer need intensity' and 'time to market' show the probability that the scores reflect the majority's opinion, which will need further study in order to substantiate the existence of these differences. The factors on which no conclusion can be drawn on their differences or lack thereof are:

- Competitive intensity
- IP landscape
- Customer landscape
- IP landscape
- Strategic fit
- Competences fit
- Attainable market size
- Market newness
- Industry rigidity
- Addressable market size

Table 12. Average scores and modes for each factor in each phase. Green represents correspondence between score and mode, yellow a slight correspondence and red low correspondence.

Factors	**Pre-phase zero**		**Phase zero**		**Phase one**	
	Score	*Mode*	*Score*	*Mode*	*Score*	*Mode*
Competitive intensity	3,1	3	3,2	4	3,1	3
IP Landscape	3,1	3	3,3	4	3,5	4
Customer landscape	3,0	4	3,0	3	3,3	4
Strategic fit	3,6	4	3,3	4	3,4	4
Competences fit	3,4	3	3,5	4	3,3	4
Market growth	3,1	3	3,3	3	3,1	3
Customer need intensity	3,7	4	3,7	4	3,6	4
Technology newness	2,9	3	3,1	3	2,9	3
Attainable market size	3,4	4	3,4	4	3,2	3
Time to market	3,0	3	3,3	3	3,4	3
Market newness	-	-	3,4	4	3,2	3
Industry rigidity	-	-	2,8	3	2,5	2
Addressable market size	-	-	3,7	4	3,5	4
Potential of substitution	-	-	3,2	3	3,2	3

In order to determine the source of the wide spread of the scores given to these factors, the data needs to be pulled apart based on the backgrounds of the respondents. Even though all respondents qualified in terms of the requirements set for their backgrounds, their spread in opinions reflects the fuzzy nature of the fuzzy front end. The data can be pulled apart into two 'camps': the first is based on the type of innovation ('blue box' or 'red box') the respondents are involved in, while the second is based on the decision-making role (or level in the organization) the respondent finds him- or herself in.

'BLUE BOX' PROJECTS VS. 'RED BOX' PROJECTS

The first category considered for further analysis of the source of the wide spread in opinions is the distinction between two types of innovation that the respondents are involved in. It should first be noted that all respondents have knowledge of disruptive innovation processes, either through direct involvement or through participation in discussion panels on the best practices considering disruptive innovation processes. Within DSM, the term 'blue box' is used when referring to innovations that have an incremental nature, while 'red box' is used for the truly disruptive ones. For simplicity reasons, the respondents situated within the Innovation Center are grouped as the ones involved in 'red box' projects, while the ones outside of the Innovation Center are considered as 'blue box'. This resulted in a data set that considered 10 sets for 'red box' innovations, while 5 sets were obtained for 'blue box' innovations. As a total of 5 respondents for 'blue box' innovations is quite low, a survey was sent to the 'blue box' respondents that have not participated in the panel due to time constraints at the time of execution. Two of these respondents have indicated their willingness to participate in that last survey, where they were only required to rank the factors to their importance, as described in section 5.2.1. Thus, this yields 7 data sets for the 'blue box' category. Despite the lack of data on the 'blue box' side, an indication of the opinion spread may be derived. The 'red box' respondents' scores for each factor in all three phases of the structured fuzzy front end model are presented in Figure 24. As was the case previously, the error bars are still very large, indicating that the 'red box' professionals also disagree among each other.

The pattern observed for the 'red box' scores (Figure 24) is very similar to the pattern obtained for the totality of the data set (Figure 20). This is explained by the dominant presence of 'red box' respondents in the panel. In the case of the 'blue box' scoring, the error bars still indicate a wide spread in the opinions among the 'blue box' respondents (Figure 25). However, the pattern of the 'blue box' scores is very different from the pattern observed in the 'red box' responses. In order to further highlight these differences and compare the spread of each factor per phase for 'red box' and 'blue box', the scores for each factor per phase are plotted separately (Figure 26).

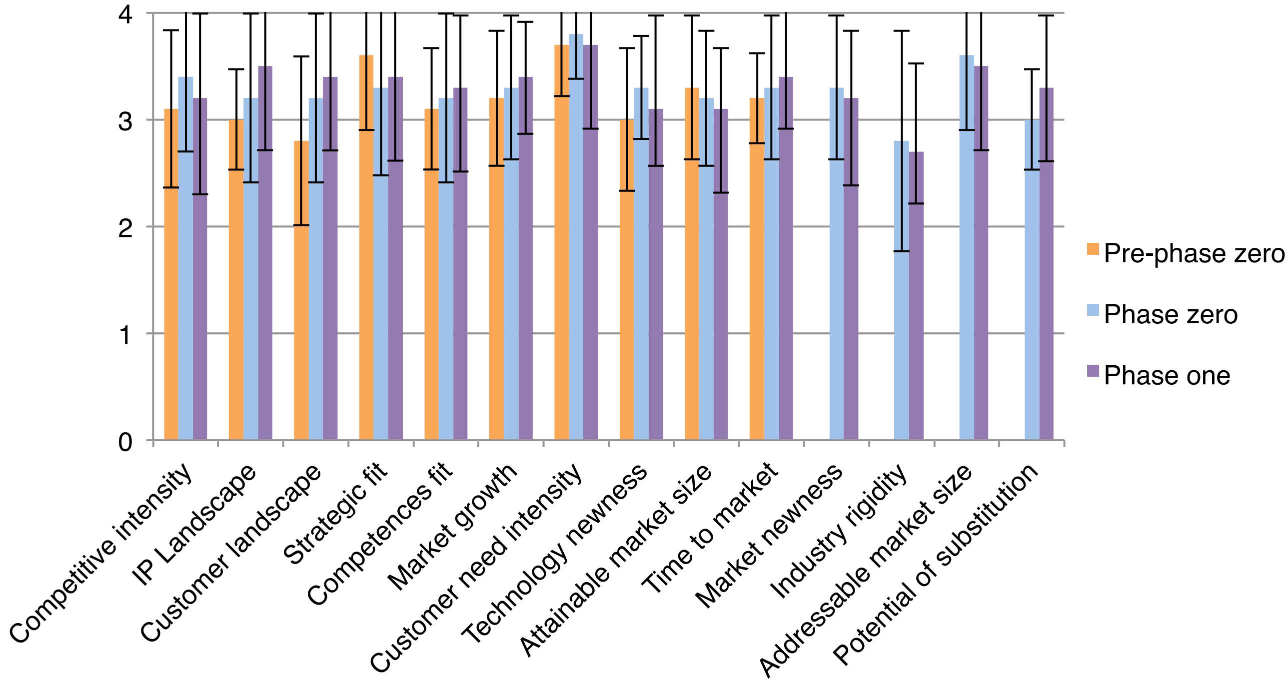

Figure 24. The average scores of 'red box' participants for the assessment factors of pre-phase zero, phase zero and phase one of the fuzzy front end model. The error bars represent the standard deviation of the data set for each factor.

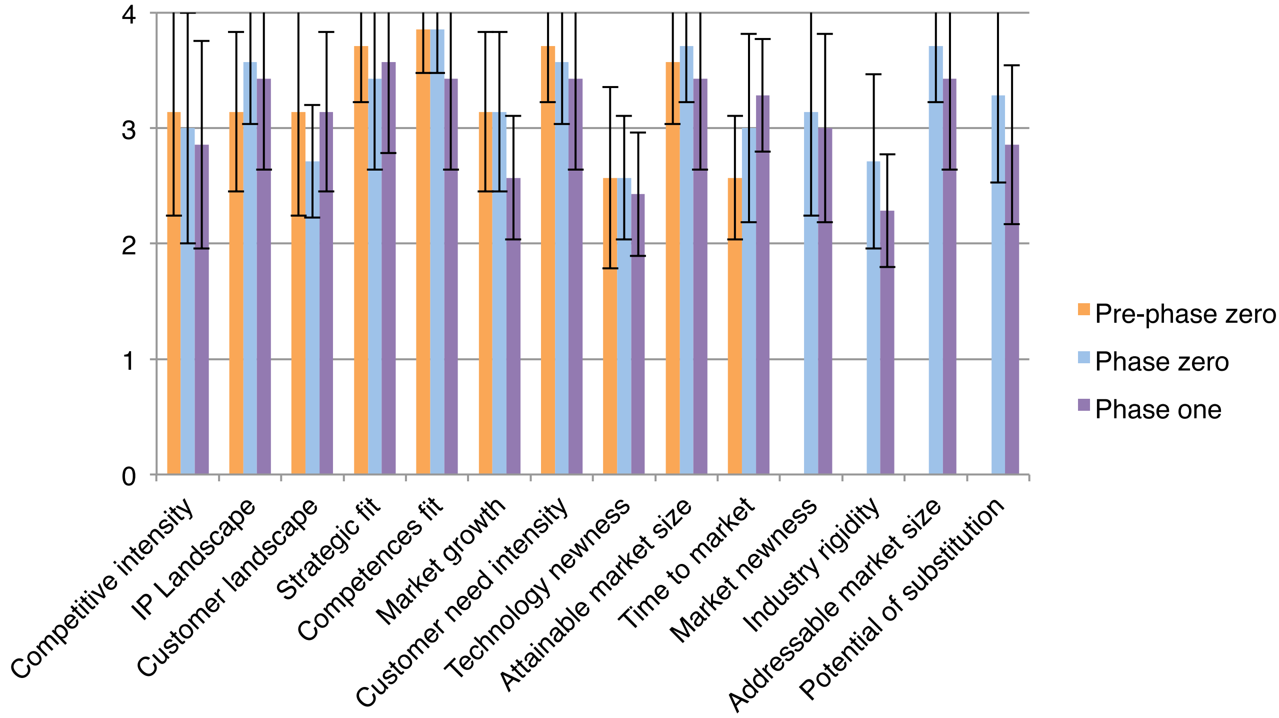

Figure 25. The average scores of 'blue box' participants for the assessment factors of pre-phase zero, phase zero and phase one of the fuzzy front end model. The error bars represent the standard deviation of the data set for each factor.

When considering the differences between the ‘blue box’ and ‘red box’ scores in Figure 26, one can conclude that the ‘blue box’ experts generally do not agree with the ‘red box’ experts. One would expect this disagreement, as incremental innovations bring about fewer uncertainties than is the case with disruptive innovations. Moreover, incremental innovations originate from improvements made on existing products, meaning that the overall strategy used for these products is based on current competences and fit with the present knowledge. In contrast, disruptive innovations will not fit with current competences or knowledge, as the products originating from these innovations are disruptive to the company, the market or both. However, the error bars in each of the cases still overlap: neither factor indicates that the difference between the scores is significant. Therefore, the difference in the type of innovation is not the source of the varying responses.

ORGANIZATIONAL LEVEL OF PARTICIPANTS

Another possible source of the apparent disagreements between the panel participants is the organizational level of these participants, or their role in the decision-making process. From the interviews with internal experts (see chapter 4), the interviewees with decision-making power had different views on the effectiveness of the decision-making process than the interviewees with supporting or consulting roles. In general, they agreed on intuition playing a major role in these processes, but they disagreed on the degree of rationality that is maintained through the seemingly rational stage-gate approach. Therefore, their opinions on the score of each assessment factor in the different phases can differ as well. Moreover, the positions of the panel members vary in terms of the phases of new product development in which they are involved. For instance, the panel partly consists of Ideation Managers, who are involved in the earliest stages of the fuzzy front end, while Project Directors will have a general overview of this stage. Thus, the differences in positions between the panel members can cause the diversity of allocated scores to the assessment factors. These differences are presented per phase of the proposed model (Figure 27, Figure 28, Figure 29).

In order to accentuate the differences, the panel members are grouped according to their positions within DSM. These position groups are:

1. Project Directors, containing all project directors and program manager;
2. Innovation Managers, containing all innovation managers;
3. Ideation Managers, containing the ideation managers;
4. Business Development, containing the M&S Platform Manager and the New Business Development Manager;
5. Business Managers, containing the VP Global Incubator and the Business Manager.

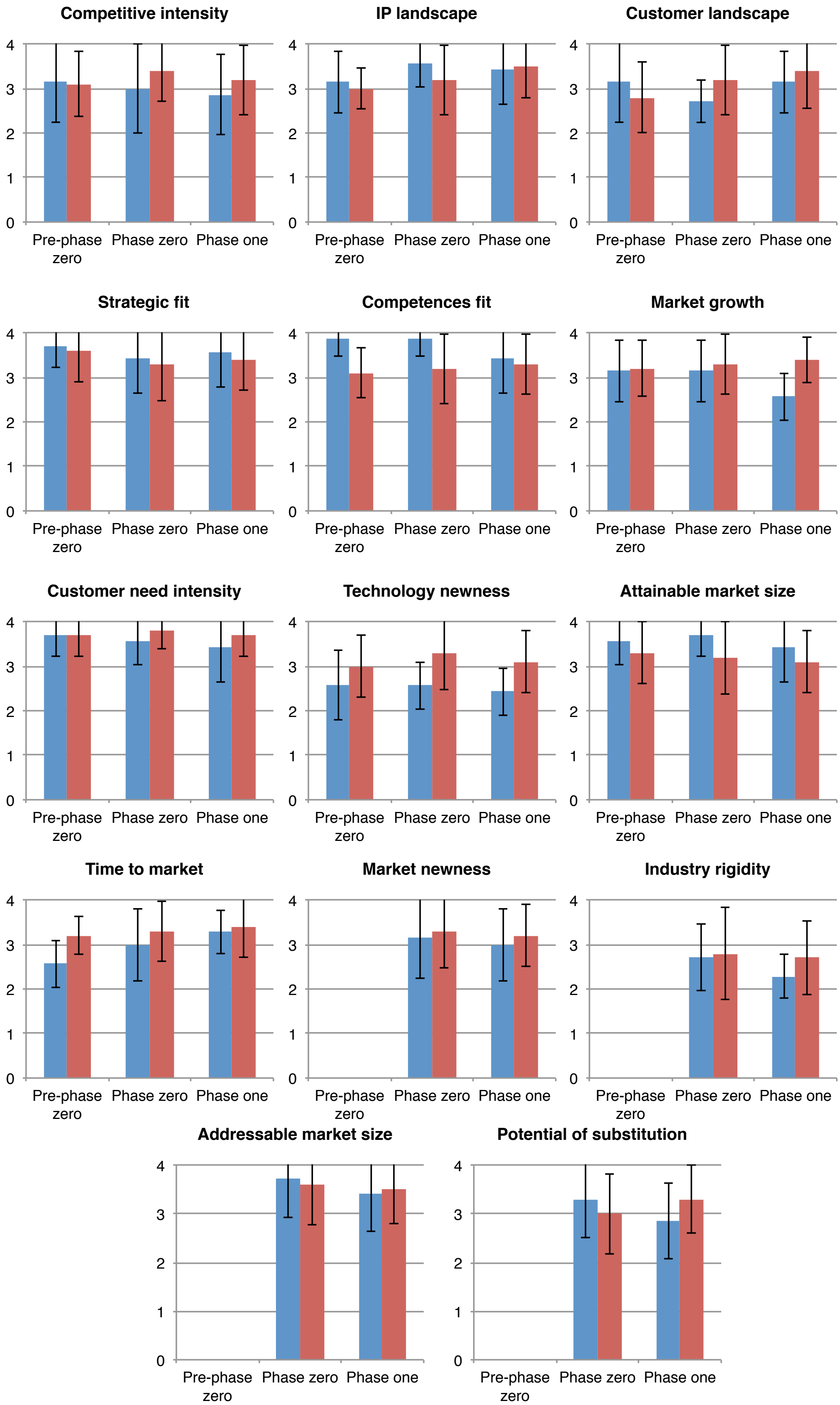

Figure 26.The average scores of 'blue box' and 'red box' participants for each factor per phase. Blue bars: 'blue box', red bars: 'red box'.

At a first glance, a clear difference is observed between these groups in terms of their involvement in the fuzzy front end. For instance, Ideation Managers are involved in the earliest stages, while the Business Development group becomes important in later stages, when commercialization of the innovation is at hand. Moreover, the Project Directors and Business Managers have an overarching view of the fuzzy front end, though they differ in terms of their decision-making role: Business Managers have decision-making power, while the Project Directors have a facilitating role in new product development. Innovation Managers are responsible for managing portfolios of innovative projects, though these projects are positioned in later stages of the fuzzy front end.

Considering the first phase of the proposed fuzzy front end model (pre-phase zero), one can already observe that the differences in scores given by these groups are quite large (Figure 27). As was the case previously, the error bars still indicate large variations in the given scores, meaning that the differences between the scores are not significant. However, the patterns obtained for each assessment factor are quite diverse. The results for each group are as follows:

- Business Development had more interest in assessment factors linked to selling points of the innovation, such as the customer landscape and need, technological aspects as newness and time to market and market size. This is in line with the group's focus on sales and marketing activities within the fuzzy front end. Interestingly, the assessment factor 'technology newness' is ranked one whole point higher than other position groups have done. This is explained by the job description within this group, which is finding new markets or businesses for the innovation, meaning that its newness plays a crucial role.
- Ideation Managers did not consider selling points, but focused on the fit to DSM and the overall market attractiveness, as ideas are usually selected on the basis of these two factors. Factors as strategic fit, competences fit and attainable market size are commonly used as the major assessment factors for idea selection, which is also represented by the average scores obtained for each (Figure 27).

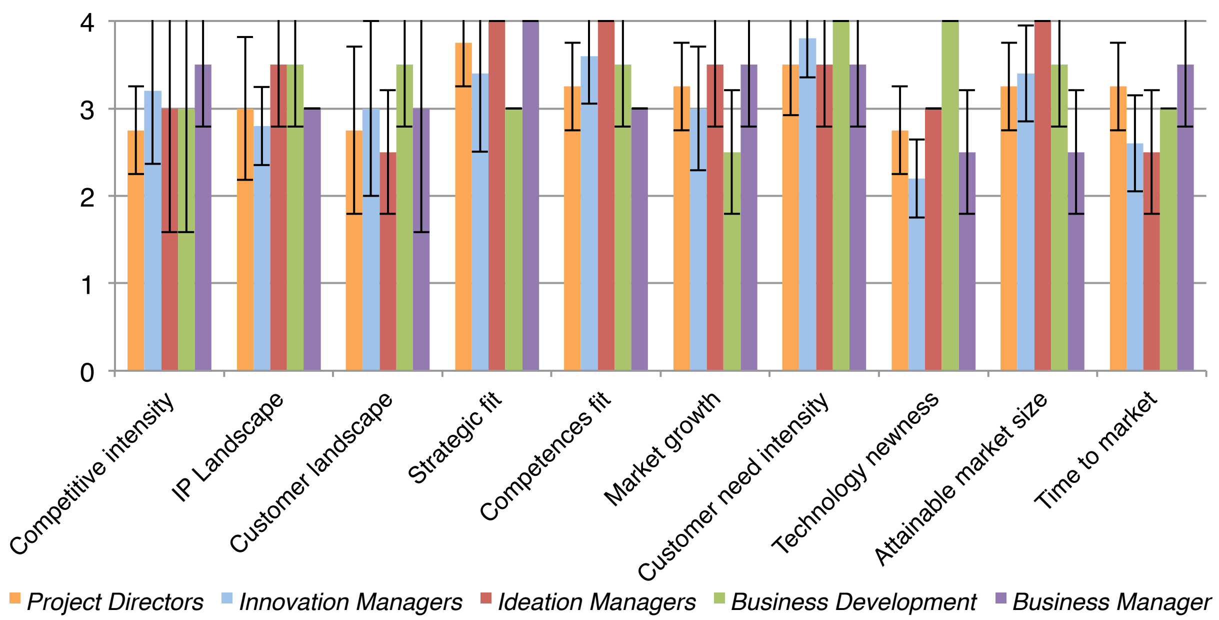

Figure 27. The average scores for the assessment factors allocated by the different position groups for pre-phase zero. The error bars indicate the standard deviation of the scores.

- As innovation portfolio holders, **Innovation Managers** have scored similar types of assessment factors highly as did the ideation managers. This group is closely involved in idea selection for the portfolios they hold, thus this result is in line with their responsibilities. The most interest was expressed in market-related factors
- **Project Directors** have demonstrated an overall similar pattern to the one observed for business managers. This group uses its overarching view of particular portfolios in supporting the decision-making process for the higher management level, which means that project directors are aware of the information needed for decision-making. Thus, a similar pattern to the business managers is expected.
- **Business Managers** have selected their most important assessment factors by considering the market attractiveness (i.e. competitive intensity, customer need intensity and market growth) and the technological attractiveness (i.e. strategic fit and time to market) of innovations. Technological attractiveness is different from the fit to DSM, as the latter needs an overlap in existing competences and a fixed strategy for product development, which is not necessarily the case for attractiveness of a technology. Business managers use this scale in order to assess the overall attractiveness of the innovation. The pattern displayed by this group indicates that their mindset is mostly commercial and hardly focusing on pure technological aspects. However, the largest difference compared to the other groups was obtained for the factor 'attainable market size', which is scored much lower by the business managers. The most probable explanation is that the business managers maintain a different definition of this factor than the other groups, who may have been confused with the factor 'addressable market size'.

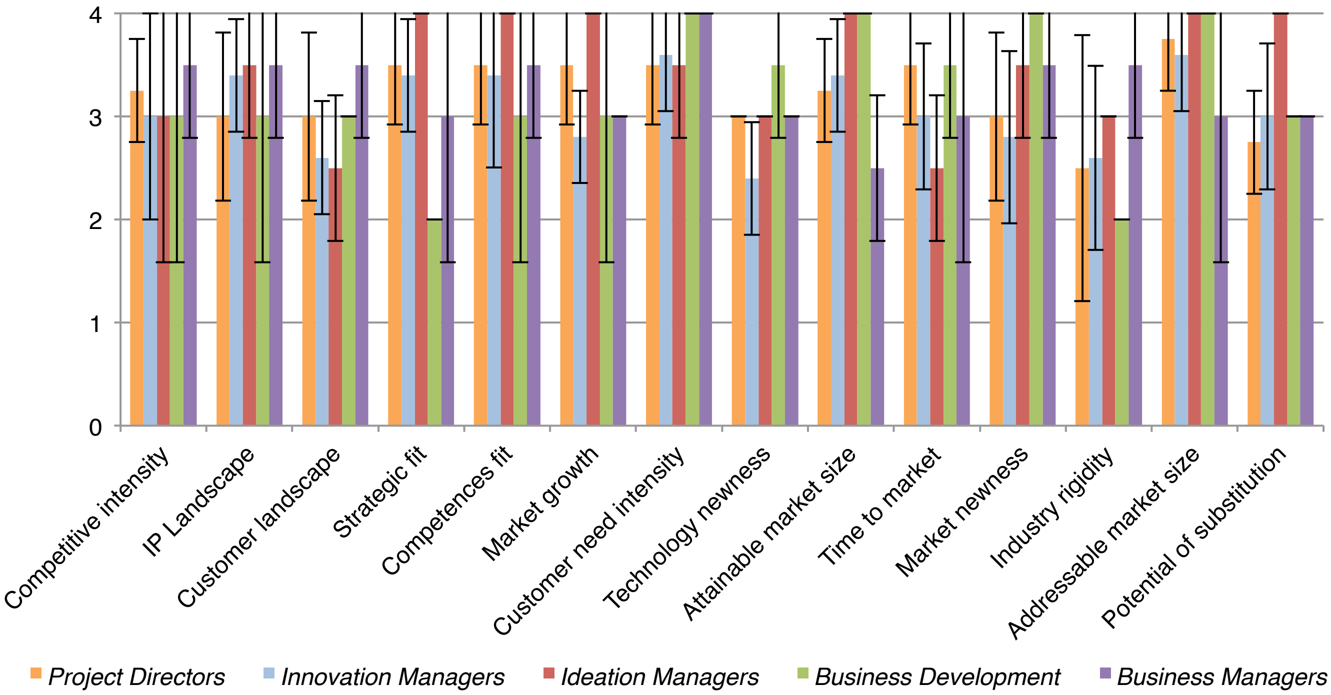

Figure 28. The average scores for the assessment factors allocated by the different position groups for phase zero. The error bars indicate the standard deviation of the scores.

The patterns of the second phase of the proposed model (phase zero) show several shifts compared to pre-phase zero (Figure 28), leading to the following observations:

- Project Directors have dedicated more importance to market factors than to technological factors in phase zero, which was also the case for pre-phase zero. Despite of this, technological factors become more important in phase zero according to this group. This is in line with the notion that phase zero considers the positioning of the innovation into the market, while pre-phase zero serves as a generator of an overarching overview.
- Innovation Managers have put emphasis on market factors in pre-phase zero, which is also the case in phase zero. However, technological factors become more important in the latter phase. This group highly values factors as competences fit and IP landscape, which are characteristic for 'blue box' participants (Figure 26). As the innovation managers mostly operate in the 'blue box' projects, this result was to be expected.
- Ideation Managers have not shown significant changes in their opinions on which type of factors are most important. Overall, in both pre-phase zero and phase zero, market factors are deemed as most important. As these managers are mostly involved in the earliest stages of the fuzzy front end, even before (i.e. idea generation), their perspective is based on market trends and customer needs rather than technological properties. They generally explore the market for unmet needs or gaps and are responsible for the generation of ideas in order to fill these needs. Therefore, the market remains the most important aspect for this group in idea assessments.
- Business Development showed a completely different pattern in some of the factors compared to the other groups. For instance, in phase zero the strategic fit and competences fit are not as important as other factors. This group is involved in developing new businesses, which do not necessarily overlap with the current knowledge or competences present at the company. Moreover, market factors are deemed as most important, which is in line with the group's focus on searching the market for unexplored segments or opportunities.
- Business Managers overall scored market factors higher on importance than technological factors. This group operates from a commercial and strategic perspective, meaning that they mostly take into account the potential of commercialization in terms of market entry, market barriers and market openings. The business managers stand out with their scores on the industry rigidity. This factor provides information on the entry barriers of the market. Their strategic mindset is emphasized by this factor, as it enables them to think of a strategy to enter the market and the ease of doing so.

When considering the last phase of the proposed model (phase one), the following observations can be stated based on the scores given by the different position groups (Figure 29):

- Project Directors have shown the same preferred interest in market factors compared to technological factors in phase one. The same reason applies as explained for phase zero.
- Innovation Managers have put more emphasis on the customer in phase one than in the other phases. From their perspective, the business case presented at the end of phase one for a large part builds upon customer relations and having these customers in place before further development is pursued. This makes sense, because an innovation's success largely depends on the presence of customers to sell it to. Also, the importance of the time to market reflects the importance of having customers in place, as this reduces a

large portion of the uncertainty of the innovation not being successful after many development time and costs have been invested.

- Ideation Managers did not change significantly in their opinions on the assessment factors: the market factors have remained most important in phase one.
- Business Development has indicated a mostly equally high importance to market factors and technological factors. This group is closely involved in assembling the business case, which needs to be presented at the end of phase one. An equal importance reflects the actual contents of a business case, which needs to combine both market and technological knowledge into one selling strategy.
- Business Managers are observed to have a similar tendency in scoring the assessment factors as the Business Development group had, aiming for an equal distribution of market and technological factors. Interestingly, the importance of the IP landscape is highest in both groups compared to other groups and other phases. As most information on the innovation is available in the last phase, the search for current IP registrations is facilitated. Moreover, from the perspective of the business managers, the IP landscape is less relevant in the earlier stages, as these stages can still provide strategies to circumvent current patents.

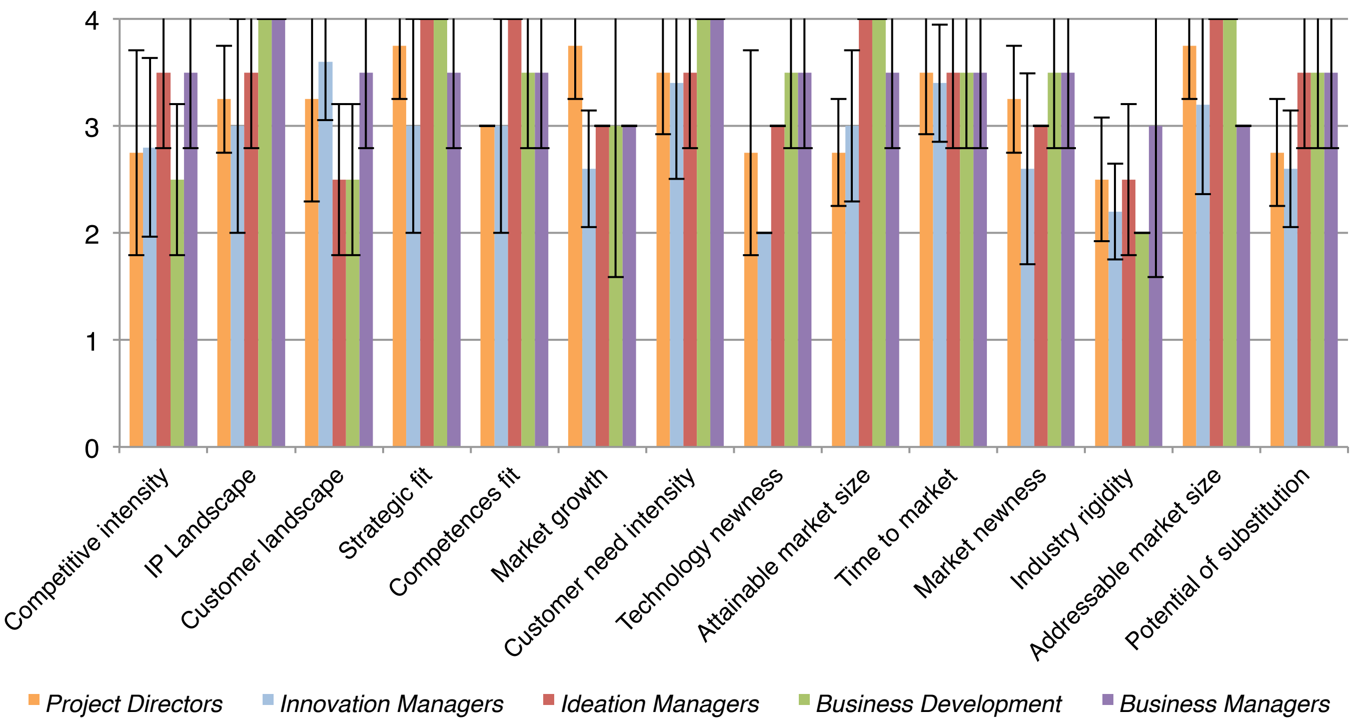

Figure 29. The average scores for the assessment factors allocated by the different position groups for phase one. The error bars indicate the standard deviation of the scores.

In conclusion, even though large variations were observed in the scores given to each assessment factor, the difference in perspective taken by each position group is evident. However, the large variations suggest that within these groups, personal opinions have significant influence on the outcome of the assessment of an innovation, as each individual pays more attention to other assessment factors than other individuals in the same group. Therefore, decision-making based on intuition is emphasized with these results, which complicates achieving a consistent list of activities within the fuzzy front end and uncertainty reduction. This thesis was based upon the notion of reducing uncertainty using a structured model, while the actual problem does not revolve around uncertainty reduction: it is about coping with uncertainty.

5.2.4. Shifts in assessment factor categories

In the previous sections, the assessment factors were discussed individually for each phase. Taking into consideration the four category factor matrix presented in Table 5, the shift of importance in the assessment factors categories for each phase can be determined and visualized. This shift indicated whether the focus within DSM lies on market factors or technological factors, either internal or external to the company. The separation of factors in categories is interesting, as this provides insight into the type of uncertainty that is strongest; the uncertainty with the largest impact requires more information for decision-making than the uncertainty with less impact.

For each phase, the four category matrix has yielded the average scores presented in Figure 30. During pre-phase zero, the technological factors gain importance when moving through the phases. More information on the technological innovation becomes available as more exploration on its characteristics is performed, which is needed for its positioning into the market. Therefore, the importance of these factors is expected to increase.

Overall, all factors are most important in phase one. Interestingly, the internal market factors gain most importance in phase one and become more important than the other factor categories. In phase one, a business case is made, which needs to be sold to the venture steering group that decides whether an innovation is further developed. In this business case, an innovation's fit with the company needs to be demonstrated, meaning that internal factors become more important.

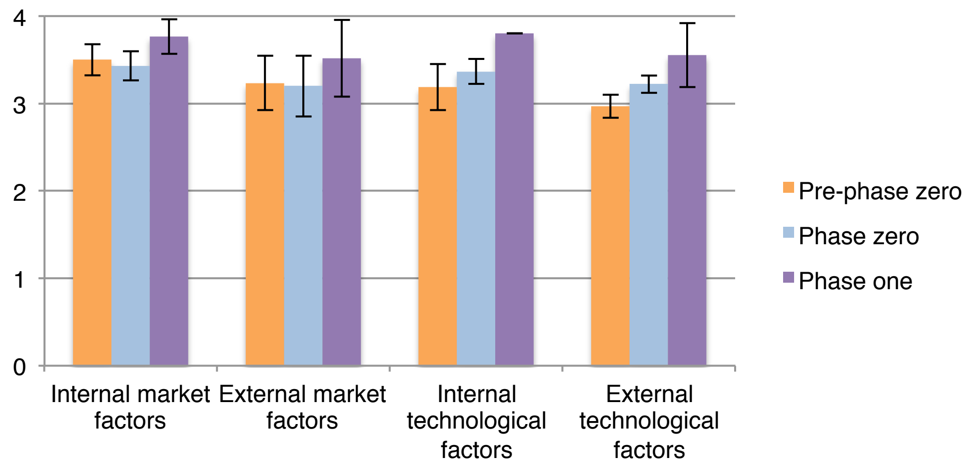

Figure 30. The average scores for each factor category in the three phases of the proposed model. The error bars indicate the standard deviation in average scores for the factors taken into account.

5.3 IMPLEMENTATION OF THE MODEL

As discussed in chapter 4, the Feasibility phase of the PMP approach was used as a starting point for structuring. The model presented in this chapter starts with one particular idea, that was obtained through the idea generation phase, while ending with a 'go' or 'no go' decision on the development of this idea. As the PMP approach maintains the same input and output for the Feasibility phase, the model is easily implemented into PMP. A schematic overview of this implementation is provided in Figure 31.

This section will further discuss the impact of the structured fuzzy front end model within the currently used methodology within DSM, by touching upon the general aspects of the model, the decision-making roles within the phases and the assessment factors upon which these decisions are based. Moreover, the cultural aspects associated within the model will be highlighted.

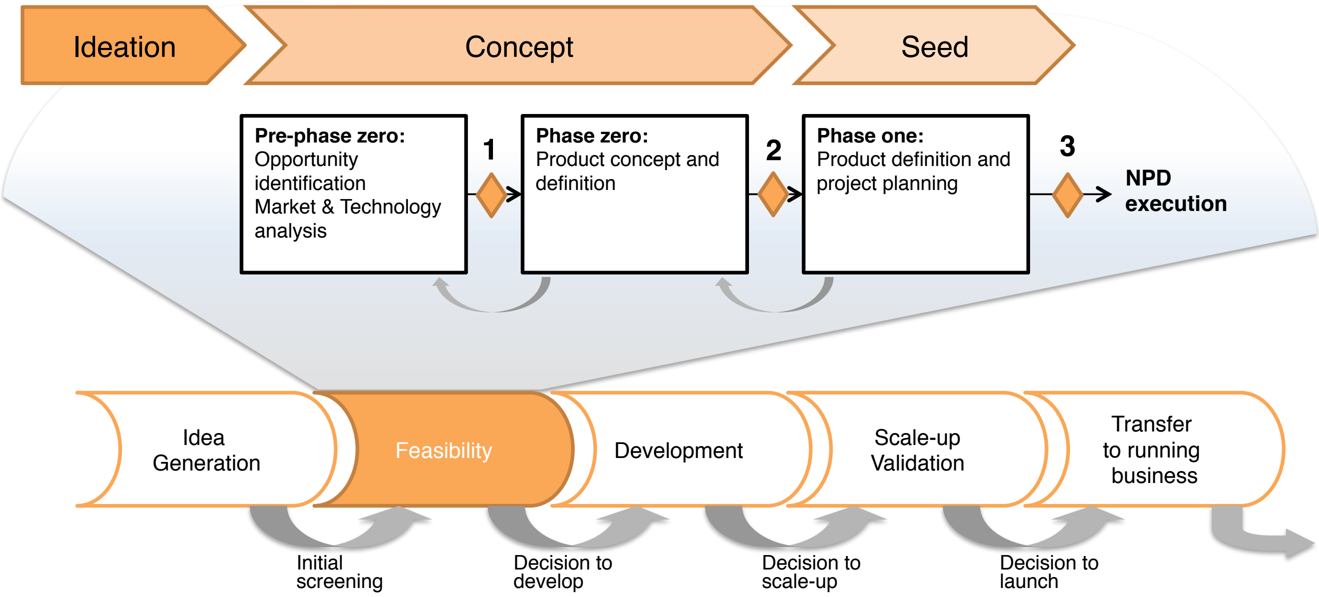

Figure 31. The implemented structured fuzzy front end model into the PMP approach. The model indicates a combination of two currently used methodologies within DSM (Bell Mason and PMP) together with the proposed structured fuzzy front end.

5.3.1. General implications of implementation

With the implementation of the structured fuzzy front end model, DSM has gained the opportunity to consider the structured model for the Feasibility phase as a potential best practice for the fuzzy front end. During the interviews with internal experts, this phase was named as the most crucial step of the fuzzy front end, which is the main reason why many discussions take place on the best practices within this phase. The implementation of the proposed structured model brings several advantages for the Feasibility phase:

- The model stimulates a more structured way of thinking due to the implementation of multiple phases with distinct information necessities and activities to be undertaken;

- Due to the implementation of multiple checkpoints (one after each phase), the progress through the fuzzy front end can be monitored more efficiently and effectively. Approving individuals involved in decision-making can base their support on the deliverables stated after each phase;

- The multiple phases in the Feasibility phase allow for more focused activities based on information gathering around the assessment factors found important in each phase. More clarity is established on the level of detail when moving through the phases, which is amplified by the set deliverables after each phase;

- The reasoning behind the decision-making in the process has become more substantiated due to the focused activities, the allocation of assessment factors and the predetermined deliverables. In the early phase of Feasibility intuition will still play a role in this reasoning, but by the end of Feasibility, this ‘gut feeling’-based reasoning will be limited.

The combination of the listed advantages yields a large impact on the reduction of uncertainties involved in decision-making processes considering disruptive innovations. However, some disadvantages can be named as well:

- By definition, the structured fuzzy front end reduces the fuzzy nature of the Feasibility phase, which is inherent to disruptive innovations. This is beneficial in terms of uncertainty reduction, but it will also reduce the flexibility one needs for handling the assessment of disruptive innovations, as some uncertainty will be present in all cases;

- Due to the wide spread of opinions of the panel in terms the importance of the allocated assessment factors, no true consensus exists on the yielded list of assessment factors. Moreover, no clarification has been gained on the weights that need to be assigned to these factors. As some may weigh more in decision-making than others, the weighting is important to consider.

The degree to which these disadvantages truly impact the assessment of a case at DSM, will be discussed in chapter 6.

5.3.2. DECISION-MAKING ROLES DURING THE FEASIBILITY PHASE

In chapter 4, the current decision-making roles within the Business Incubator of the DSM Innovation Center were discussed and allocated (Table 9). These roles will remain as they are, though more clarification is needed into the extent of their involvement in the structured fuzzy front end model, which is provided in this section.

First of all, the Vice President of the Business Incubator will still have decision-making power. At the end of the Feasibility phase, the decision needs to be made whether to move into the development of the assessed idea or product. The VP will decide if this is a ‘go’ or a ‘no go’ decision, together with the Innovation Council. During the earlier phases in Feasibility (pre-phase zero and phase zero), the VP will play an approving role, as the decisions made in these phases will not bear large consequences to the organization. However, the involvement of the Innovation Council, which has a deciding role as well, will remain limited to the end of the Feasibility phase.

Depending on the size of the project and the amount of costs involved, the Chief Innovation Officer can have a deciding, approving or informed role in the process. He will have the informed role throughout the Feasibility phase, while at the end of this phase, he will either decide to move to development or approve that decision. Usually, the CIO takes the deciding role when the budget needed for the development exceeds a certain limit (in the range of hundred thousands euros).

Second, the Business Analysts will execute the assessment studies throughout Feasibility, with cross-functional teams to support the information provision for these studies. The analysts will need the approval of the Manager of Business Intelligence and Market Research, who will remain in his approving role throughout each stage of Feasibility.

Third, the roles of the Innovation Program Office (IPO) and the Program Management Office (PMO) will remain unchanged (Consulted and Supporting, respectively). The IPO will still be consulted in terms of best practices within the innovation process, which can also mean that its members will be involved in further improvement. The PMO will keep its role in gathering information from the different departments in order to inform the Innovation Council.

5.3.3. IMPLICATIONS OF THE ASSESSMENT FACTORS

The assessment factors allocated to each phase of the structured fuzzy front end indicate the activities that need to be undertaken, as these factors stand for information that is needed to base sound decisions upon. One major implication of this allocation is the increased structuring of each phase, which facilitates the process of moving through the Feasibility phase as the decision-making in this phase becomes more rational.

The increased rationality in the decision-making process due to the allocation of assessment factors is further emphasized by the increase of predictability of the decisions that will be made. Based on the assessment factors, key success factors can be formulated for the feasibility of the assessed idea or product. Based on the research conducted in this thesis, not sufficient information is gained in order to do so: multiple cases need to be examined before one can decide on these factors.

As indicated in section 5.3.1, the disadvantage of the factor allocation is the lack of consensus on the importance of each factor in the stages of the model. Though this indicates the inherent fuzziness of the Feasibility phase, decision-making becomes more complicated when decision-makers do not agree on the type of information that is needed for sound reasoning. Therefore, more research is still needed in order to reach complete consensus on the assessment factors.

5.3.4. CULTURAL ASPECTS FOR IMPLEMENTATION

The organization of the DSM Innovation Center can be categorized as decentralized and open, where the divisions and corporate ventures have their own decision-making power to a large extent. Moreover, the CIO, who is supported by the Innovation Council, executes a supervisory role. Considering the proposed structured model for the fuzzy front end, the decision-making power is still entrusted to the Business Incubator itself. The department still has the flexibility to move through each phase in Feasibility without any bureaucratic interference from the top management layer within the Innovation Center. The Business Analysts will have most ownership of the project, which will motivate them to proceed with the assessment studies.

The major cultural aspect that arose during this research, was the wide spread in opinions on the importance of assessment factors in each phase of the model. No significant trend could be distinguished on the source of this wide spread, indicating that the fuzzy front end is strongly influenced by the opinions of individuals, not groups of individuals sharing the same department, experience or organizational level. Therefore, the generalizability and rationality of the model becomes limited, as intuition and personal opinion play a major role in decision-making. To truly accentuate the cultural impact on such model, multiple Incubators within different organizations need to be researched.

6. DSM CASE APPLICATION

Based on the structured fuzzy front end model presented in chapter 5, a case is applied to the model at DSM in order to demonstrate the effectiveness of the model and present lessons that can be drawn for further improvement. The case presented in this chapter is a feasibility study on including a new compound into the project portfolio of the Business Incubator. This chapter will position the case into the model, on which further analysis will be based. The chapter will be concluded with lessons that can be drawn from the case in terms of the model. As the main purpose of this chapter is to evaluate the functionality of the model and the case material itself is confidential, only the main findings and the analysis results will be shown.

6.1 FEASIBILITY ASSESSMENT

The assessment of the feasibility of including the new compounds in the project portfolio of the Business Incubator is based on the structured fuzzy front end model presented in chapter 5. First, this section will determine the position of this case in the model, after which the methodology for analysis is explained. Afterwards, the analysis of the case is performed taking into account the assessment factors determined important for the phase of the model, where the case is positioned. As a conclusion, a recommendation for a strategy regarding the new compounds is formulated and key assumptions and boundary conditions are listed.

6.1.1. CASE POSITIONING IN THE MODEL

The positioning of the case into the proposed model is based on the advances and efforts that have been made internally thus far. At the moment of writing, multiple divisions within DSM are testing the performance of the new compounds in two main applications. These efforts are combined in a Joint Development Agreement (JDA) with a development partner.

The development efforts have been scattered among several departments, which made the positioning of the case into the model challenging. However, when taking into the account the activities undertaken and the problem statement, the following observations can be derived:

- An initial market- and technological screening has already been performed, which resulted into a JDA;
- The functionalities of the new compounds were already researched, which had yielded research efforts in two fields;
- No strategy has yet been formulated on the development of these compounds. Initial discussions have started to arise on this strategy.

Comparing the characteristics case thus far with the activities formulated for each phase of the proposed model (Table 10), the case is positioned into phase zero of the model (Figure 32). Based on the assessment factors of phase zero, the assessment methodology will be further explained in the next section.

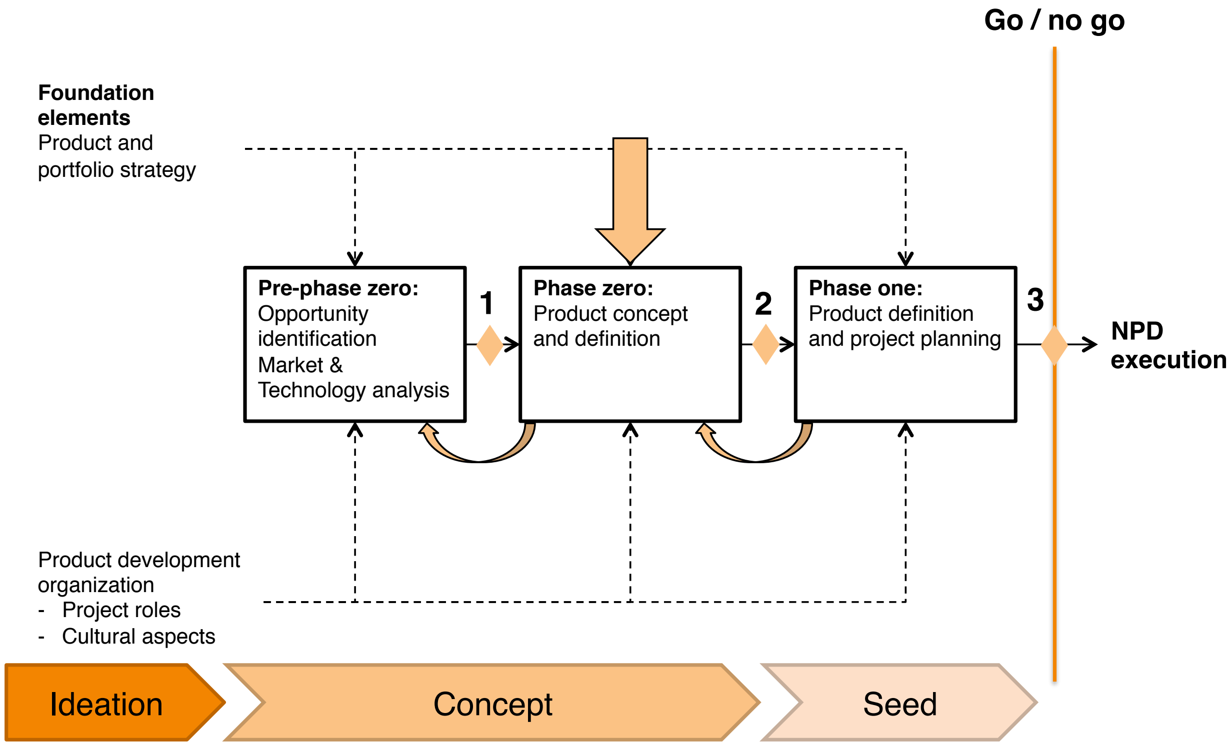

Figure 32. The positioning of the case into the proposed model, indicated by the arrow.

6.3.2. Analysis methodology

In order to provide a sound analysis of each assessment factor determined for phase zero, information needs to be gathered based on these factors. The factor list taken into account for phase zero, is presented in Figure 33.

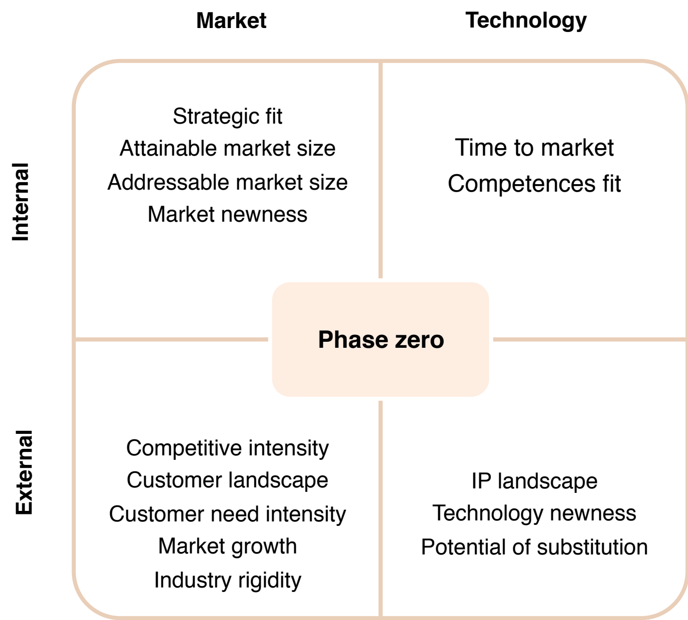

Figure 33. The assessment factors taken into account for the case.

This section will provide an overview of the methodologies used for information gathering, as well as the assessment itself.

Information gathering methods

LITERATURE

In order to gain an initial understanding of the market segments the new compounds may be positioned in, a literature study is conducted in secondary information sources. These sources are online press releases and market research reports on these compounds developed by renowned market research bureaus. These information sources provide the basis of understanding of the structure of the market segments, general trends and customer needs, the competition in the segment and the market size and growth.

INTERVIEWS WITH INTERNAL EXPERTS

Next to information on the market side, an understanding needed to be gained on the current internal developments regarding the new compounds. To this end, the people involved in the new compound research were interviewed through a semi-structured interview in order to obtain knowledge on the product performance in that particular segment, while gaining insights into the fit with the current organization, the newness of these compounds and the customer needs. Moreover, internal experts in other fields were consulted: at the department of Intellectual Property, a request was put in to screen the IP landscape for the new compounds and their production.

INTERVIEWS WITH EXTERNAL EXPERTS

For more detailed insight into the customer need intensity and currently used strategies for the development of the new compounds, competitors and potential customers were interviewed by telephone in a structured manner. These interviews also provide information on the potential of substitution of currently used compounds by the new compounds and the degree to which the new ones are more interesting in terms of the price/performance ratio.

Analysis methods

FACTOR SCORING

For each factor, a score range was determined based on (if applicable) quantitative information obtained from the information gathering methods. The scores given to each of the factors ranged from 0 to 4, where 0 was indicated as least attractive and 4 as extremely attractive. By quantifying the ranges as much as possible, the ranking becomes more rational, which is the basis of the model. The scores for each factor were allocated per market segment for the new compounds.

VISUALIZATION

The scores of the assessment factors need to be visualized in such a way, that each factor can be seen separately, while the complete picture can still be considered. As this has been indicated a demand from the internal experts, the currently used visualization methodology was researched. This method was screened its advantages and disadvantages, upon which an alternative was developed.

6.3.3. Analysis results

Based on the methodology described in section 6.3.2, the yielded information provided the basis of the analysis of the feasibility of the new compounds' development by the Business Incubator. This section will first explain the visualization methodology that is developed based on the scores allocated to the assessment factors, in comparison with the methodology that is currently used. Afterwards, the resulting visualization is applied to all market segments targeted for the new compounds' positioning.

During the interviews with the decision-making experts, some of the interviewees have emphasized on the importance of the complete picture when making the decision to move from one phase to the next in assessment studies. Currently, the complete picture is obtained by producing a bubble diagram. This diagram takes into account two main categories: the market attractiveness of the product applied to various market segments, and its fit to DSM in terms of strategy and competences. The bubble size is usually taken as the market size. When applying this visualization method to the structured model and its allocated assessment factors (Figure 33), two main categories are identified based on the factor categories: market attractiveness and technological attractiveness, both projected to DSM. Taking market size as bubble size, Figure 34 is yielded as a result.

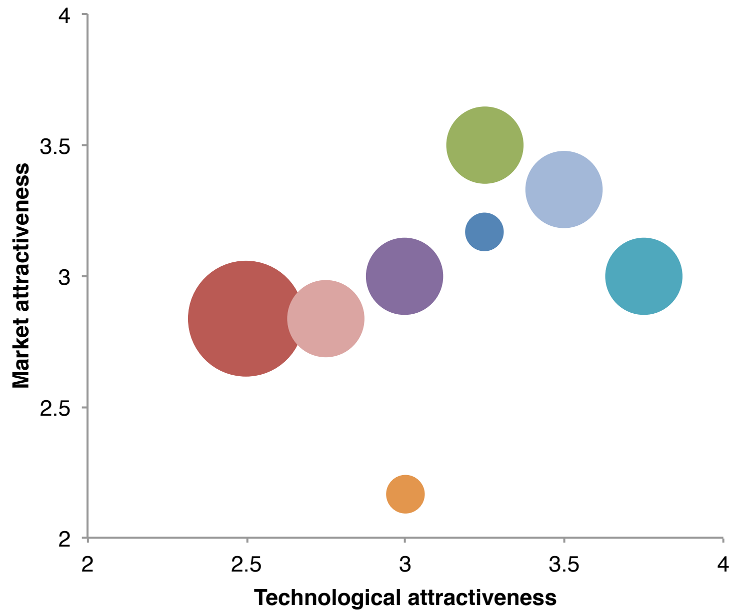

Figure 34. A bubble diagram positioning the market segments targeted for the new compounds. The bubble size indicates the market size of the indicated segment.

The bubble diagram can provide the decision-maker with an indication on the overall attractiveness of each market segment based on the position of the bubbles and their sizes: the more the bubble is located in the upper right corner of the diagram, the more attractive the visualized segment is, combined with a large bubble size. For creating a complete picture on a product's and its market segment's attractiveness, the bubble diagram is fairly effective. However, some problems are encountered when using this method as a basis for decision-making:

- The two categories along the axes are the averages of scores dedicated to a variety of factors. These averages generalize the scores given to these factors, while these scores can have a large spread among them.
- One factor can be more important than other factors. By combining the scores of more important factors with less important factors into one average, the generated bubble will not distinguish on the attractiveness among the more important factors.

The evident disadvantages of the bubble diagram call for a visualization method where the complete picture can still be visualized within one glance, though the level of detail in terms of individual assessment factors is still ensured. The solution for this problem lies in the creation of a so-called ‘spider diagram’ (Figure 35). As an example, one market segment is taken for the visualization. Based on scores given to each factor on a scale of 0 to 4, the attractiveness of one market segment is derived from the ‘fullness’ of the diagram: the more filled the spider diagram is, the more attractive a market segment is. Next to this generalizing feature, the diagram still allows to look into more detail considering the scores given to each assessment factor. In the example of the market segment (Figure 35), the scores vary from 1 to 4, indicating that taking an average over two categories would generalize this spread.

Figure 35. A spider diagram for the assessment of one application for the new compounds.

The spider diagram is incorporated in the model as a supporting tool for the assessment of the attractiveness of the market segments identified. The remaining market segments are presented in Figure 36. Judging from Figure 36, the degree of fullness obtained varies among the segments when focusing on the complete picture. Moreover, the distribution of scores is also varied, which indicates that the market segments have different characteristics considering the positioning of the new compounds. Based on these visualizations, a recommendation for a strategy for DSM can be formulated. This recommendation will not be discussed, as it contains confidential information that could not be disclosed.

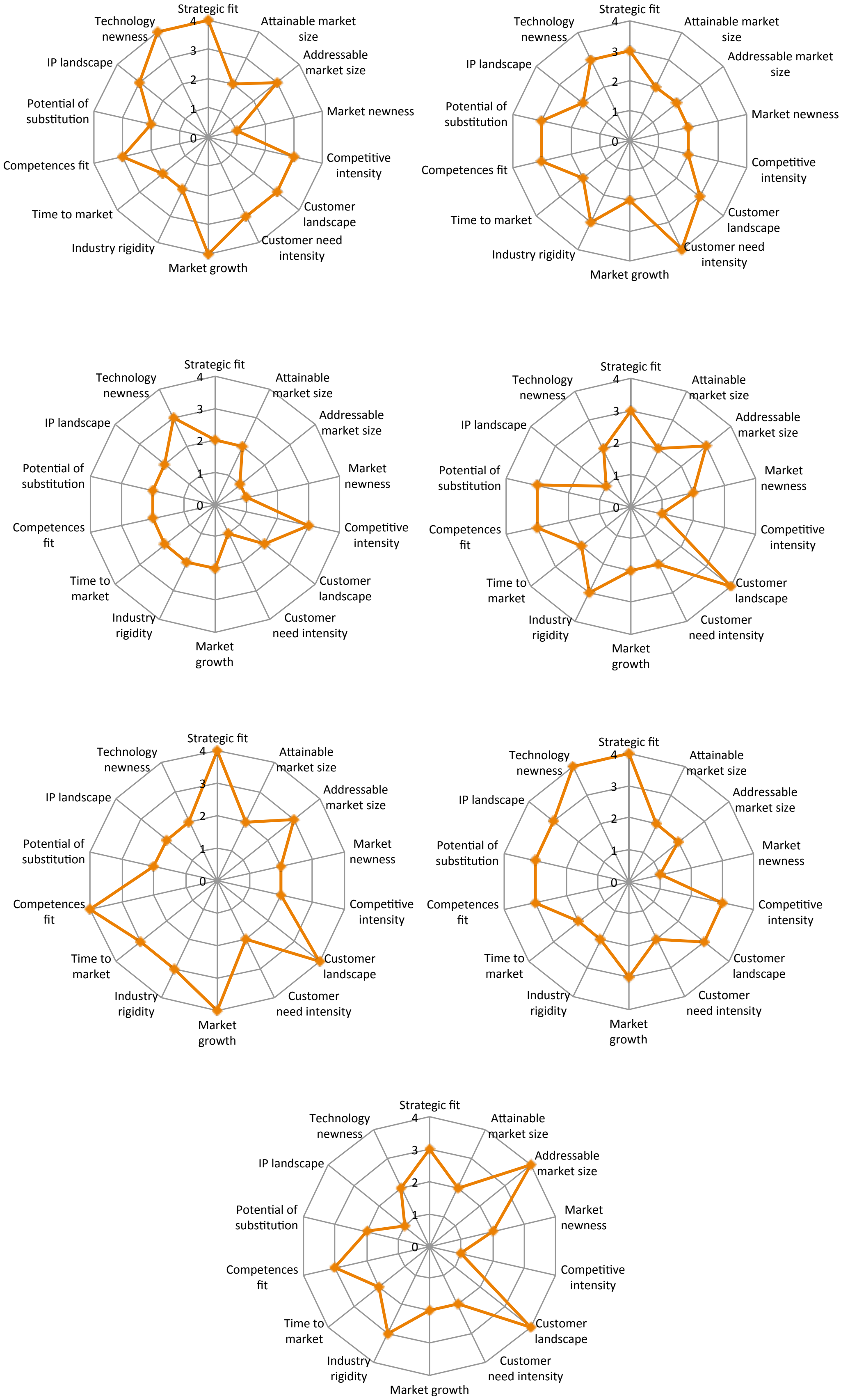

Figure 36. Spider diagrams for the other market segments identified.

6.2 LESSONS FROM THE CASE APPLICATION

By applying the case to the structured fuzzy front end model, lessons are drawn on the effectiveness and applicability of the model on such assessment studies. It should be noted that this reflection can only be based on phase zero of the model, as that is the phase in which the case is positioned. Therefore, the focus of this segment will be limited to this particular phase.

The first observation made when considering the analysis from the model is that the visualization of factor scores is presented in a comprehensive and clear manner. The decision-maker can decide to settle for a spider diagram that is as full as possible, but also has the possibility to look at each assessment factor score separately without using additional visualization methods. Currently used methods, such as the bubble diagram, generalize assessment factors based on two categories, which mostly focus on market attractiveness on the one hand and the fit to DSM on the other. Through the generalization of assessment factors, key success factors for the project become lost in an average score, while the spread between the scores can vary greatly. Therefore, the spider diagram considering all assessment factors separately provides more detailed information than a bubble diagram, while still enabling the decision-maker to see the complete picture.

Moreover, the model has enabled a structural approach for handling the case and the identification of missing information versus information that is already available or worked out internally. With having a list of assessment factor for one phase, the methodology for gathering the needed information is easily determined. Due to the clarification of activities and needed information, the positioning of a case also becomes straightforward.

Next to the advantages that the model brings in the case assessment, some clear disadvantages could also be determined. These disadvantages are all closely linked to the completeness of the assessment study:

- *First mover advantages versus first follower advantages*
  When developing disruptive innovations, an organization can assume that the product that is developed is completely new to the market. However, other organizations may also be in the process of producing the same type of product for similar applications without making this public knowledge. If DSM's strategy were to be a pioneer, the company would want to make sure that the development of the product could result in a timely market introduction before the other organizations do so. Moreover, these organizations may have already endeavored on a market introduction of this product, meaning that an organization as DSM will not benefit from first mover advantages, though many learning advantages are reaped when being a first follower. The model does not compare the advantages of being the first to bring the product to the market and of being in a following position, which is of importance to decide upon a development plan.

- *Weighting of factors*
  Due to the disagreements within the panel study discussed in section 5.3, no weighting of factors could be applied to the case. In practice, some factors can be more important to consider than other factors. Due to the limited amount of assessment factors listed for each phase of the model, weighting can become especially important, as differences in scores can be spotted straight away.

- *Market newness, technology newness & product newness*
  In the interviews conducted with internal experts, the need for a diagram where the newness of the idea or product can be assessed was indicated as being important. This diagram would consider three axes: market newness, technology newness and product newness. If the product scored high on two of these axes, it would be interesting to consider for the Business Incubator. In the case of a high score on all three, too much uncertainty would be involved in pursuing the product's development. During the panel study, only market newness and technology newness were listed as important assessment factors, while product newness was left out of the lists. As a result, the degree of newness of the product can only be decided based on two axes when using the model.

- *Niche applications versus large-scale applications*
  The platform potential of a product within the Business Incubator strongly depends on a certain profitability threshold that needs to be realized within 10 years. Though this factor was incorporated in the assessment factors 'addressable market size' and 'attainable market size', no distinction is made on the scale-characteristics of the targeted markets. The model does not yield a conclusion on the pursuit of niche applications or large-scale applications, which is strongly tied to the pricing model that can be deployed, along with the volume that can be produced by DSM. It should be noted that this disadvantage can originate from the characteristics of the phase the case was positioned into: phase one would already provide insight into the advised pricing strategy along with a detailed hypothesis for product positioning into the market.

In conclusion, the model has obvious advantages in aiding the assessment process of new ideas, but lacks certain elements that complete the picture of the situation at hand. However, the (dis)advantages listed here are based on phase zero of the model, meaning that validation of the complete model would determine the degree to which these still play a role.

6.3 EVALUATION OF THE MODEL

In section 3.5 a list of requirements was provided, which the structured fuzzy front end model needed to comply with. These requirements are summarized below:

1. Uncertainty reduction in both market and technology
2. Strategy alignment
3. Decision-making roles division
4. Ease of use
5. Flexibility
6. Applicability at DSM

With the application of the case, insight is gained on the functionalities of the model respective to the requirements set for this model. Taking the insight from the case and the implementation of the model presented in section 5.3, the model is evaluated for each requirement in the following sections. As the case applied to phase zero only, the requirements cannot be reflected upon considering the model as a whole.

6.3.1 UNCERTAINTY REDUCTION

The requirement of the reduction of uncertainties was aimed at two aspects: technological uncertainties and market uncertainties. The manner in which these uncertainties were reduced was by introducing assessment factors, which covered market aspects and technological aspects, and provided the information needed for decision-making considering the innovation. Each phase of the model contains a list of assessment factors, of which the phase zero factors were used for the assessment of the case.

Market factors had the most emphasis, as the panel members have selected more market factors to be important than technological factors (see section 5.2). The reason for selecting more market factors is that the impact of market uncertainties is larger than the impact of technological uncertainties in disruptive innovations. Therefore, a larger representation of the market factors in the model is needed.

As indicated in section 6.3.3, the bubble diagram was commonly used at DSM as an illustration of the assessment results. However, the generalization of factors can lead to a distorted view of the complete picture, as scores given to each factor can vary significantly. The amount of uncertainties in both the market and the technology are not reduced with this generalization, but rather amplified. Making a distinction between the different assessment factors, but still maintaining a complete picture, combated the uncertainty reduction combated successfully.

However, one should note that the uncertainty reduction could be counteracted by the subjectivity of the scores given to each assessment factor. The solution for this problem lies in quantifying the assessment factors: by applying distinct and consistent ranges of data for each possible score, the objectivity of scoring is increased, which in turn decreases the impact of uncertainties.

6.3.2 STRATEGY ALIGNMENT

The model allows for an alignment with the strategy on any level of the organization (i.e. corporate, portfolio and product). Each phase has strategy benchmarking built in, in the sense that all activities undertaken are aligned with strategic considerations. The strategy alignment is achieved by incorporating an undisclosed deliverable within 10 years into the factors ‘addressable market size’ and ‘attainable market size’. This deliverable is the most important strategic consideration for the Business Incubator, as indicated by respondents 1 and 3 during the interviews (section 4.2).

6.3.3 DECISION-MAKING ROLE ALLOCATION

The decision-making process taking place at the DSM Innovation Center is implemented into the model by assigning decision-making roles at each decision-gate incorporated in the model. Due to the nature of the case used here, the actual effectiveness of these roles could not be assessed: the case considered a feasibility study, which is performed mid-way of phase zero. However, the rationality of the decision-making can be discussed based on the case.

As indicated in chapter 4, several interviewees have stated that the complete picture is important for an assessment, while others have mentioned the irrationality of this assessment. The model has provided a way to obtain a complete picture, while the possibility of a detailed view is present, taking away the irrationality of the decision-making process.

6.3.4 Ease of use

The activities prescribed in the structured model depend on the assessment factors allocated to each phase. As the panel study has yielded these lists for each phase, the activities required also became clear, because they need to be aligned to the type of information needed. The scoring of each factor has been simplified by assigning quantifiable ranges to every possible score. Therefore, the model provides a structured guideline for the assessment of disruptive innovations, which makes it very easy to use for the employees who execute the projects.

The same holds for the interpretation of the displayed results in the spider diagrams. The decision-makers prefer to see the complete picture, which is possible with this method of data presentation. Moreover, the level of detail in these diagrams enables the decision-makers to see in one glance if the variety in scores is large. Even though no indication could be derived for the weighting of assessment factors, one can imagine that the importance of each assessment factor can be based on the characteristics of the innovation itself. If the innovation were mostly new to the market than to DSM, the focus would lie on the market, while the opposite holds when the innovation is new to the company instead of the market. Therefore, the differences in the types of innovations are represented in these spider diagrams, which facilitate the interpretation of the results.

6.3.5 Flexibility

The flexibility in the model is promoted by the existence of feedback loops, which enable the project executor(s) to refer back to a previous phase if new information is obtained that change the assessment of an innovation significantly. However, this could not be tested with the case, as the case covered a small portion of the model.

6.3.6 Applicability at DSM

The implementation of the model was demonstrated in section 5.3, where the structured fuzzy front end was positioned into the PMP process. Due to the alignment of deliverables, the model fitted well into this process and provided a structured way to move through the process' Feasibility phase. Moreover, some of the respondents had indicated that an integration of the Bell-Mason framework and PMP would be beneficial for decision-making at the DSM Innovation Center. The model has achieved this integration of both methodologies for the fuzzy front end. Moreover, DSM does not need to change its organization regarding new product development in terms of current decision-making roles as well as the focus on the PMP approach. Therefore, the applicability of the model at DSM is high considering the integration of methods and the lack of necessity to change the existing process.

7. RECOMMENDATIONS FOR FUTURE RESEARCH

Based on the conducted research and the proposed structured model, several recommendations for implementation at DSM were discussed in section 5.3. In general, the model could be implemented into the existing framework around product development. However, some disadvantages were tied to the proposed model. First of all, the degree of flexibility is reduced, which is still needed when working with the fuzzy stage of disruptive innovations. Second, the allocated assessment factors could not be analyzed on their importance, as a lack of consensus arose during the panel study. Though the spread of opinions is a characteristic of the fuzziness of this process stage, rational decision-making can merely be based when a consensus exists on the decision-making criteria. Next to the recommendations made for the implementation of the model, lessons could be drawn from the application of the DSM case to the model, which are discussed in section 6.4. Apart from the organizational and case-specific discussions held on these recommendations, general shortcomings of the model and the conducted research can be named as well. This chapter will discuss these shortcomings and provide suggestions for future research.

7.1 THE GENERALIZABILITY OF THE PROPOSED MODEL

The structured fuzzy front end model was developed during an internship placement at the DSM Innovation Center, more specifically at the Business Incubator. The interviews held with the internal decision-making experts and the conducted panel study have focused on the internal organization and culture, which has resulted in a strong DSM influence on the model in terms of the allocation of decision-making roles and the assessment factors for each phase. The allocation itself is therefore not generalizable to other organizations that have Incubator-like divisions for disruptive innovations. However, this research has developed a method with which other organizations could determine the decision-making roles and the allocation of assessment factors. The interviews with internal experts and the panel study have proven to be effective in gaining insight into both categories and can serve as a starting point for the allocation procedures.

Moreover, the structured fuzzy front end was shown to fit perfectly into the currently used methodology for monitoring product development (the PMP approach). This approach is utilized in the entire DSM organization. Within several DSM business groups in the Netherlands and Switzerland, discussions were ongoing on the best practice to move through the Feasibility phase of PMP. The experts from these divisions were asked to participate in the panel study based on predefined criteria. The lack of generalizability to other organizations is still apparent, but the generalizability to other business groups remains intact.

Apart from the decision-making role and assessment factor allocations, some aspects of the model are still applicable outside of DSM, as these are based on literature studies. First of all, the activities and deliverables outlined for each phase were not formulated specifically for DSM, but were based on the descriptions provided in the literature of the models that were fused and structured. Therefore, the resulting structured model has contributed to create a best practice on moving through the fuzzy front end of product development in the case of disruptive innovations.

Considering the aspect of generalizability, the recommendations for future research would be to perform a cross-organizational research with companies that have Incubators installed in their organizational structure in order to stimulate disruptive innovation processes. For instance, the Dutch firm Philips has such an Incubator installed for the new ideas that are generated within the organization. By using the method proposed in this research (i.e. interviews on decision-making and a panel study for factor allocation), the generalizable nature of the model can be studied.

7.2 SAMPLE SIZE

Within DSM, a limited amount of employees are directly involved in monitoring disruptive innovation processes, let alone innovation processes in general. The Innovation Center is at the heart of these operations, which is thus the basis of recruiting the interviewees and panel members. The amount of interviewees was deemed as sufficient to gain insight into the decision-making process involved in the Business Incubator as part of the Innovation Center as a whole. Considering the panel study, no consensus was reached on the importance of each allocated assessment factor to the different phases of the model. The panel consisted of 15 members who responded consistently. The tracing of the source of these disagreements did not yield conclusive results, as the panel size was not sufficiently large in order for the differences to be significant.

One major problem encountered considering the panel size, is the limited amount of employees who are involved in the innovation process monitoring, especially for disruptive innovations. This raises the question to what extent such disruptive innovation process can be researched to be specific for one organizational culture in order to obtain significant results. If cultural aspects were taken into account, the recommended future research would still entail an internal investigation into the allocation of factors for these phases. The recommended approach would be to provide more detail into the panel study by implementing discussion moments after each round of surveys with all panel members. The panel members will receive the results from the previous round, after which discussions can be started on the degree to which these results are representative. Even though this is a time-consuming and difficult operation in terms of geographic locations, it will eventually yield a consensus on factor allocation and importance.

7.3 MODEL EVALUATION

In this research, the evaluation of the model was conducted through one case study that was running at the Business Incubator at the time of writing. The case was positioned into one phase of the model, yielding results that were specific for that phase of the model. This provided insight into the effectiveness of the model for this phase, but the model as a whole has not been validated through this case. Therefore, no conclusions can be drawn on the effectiveness on the model as a whole.

A recommendation for future research for the validation of the model is a cross-case analysis of cases that were executed and finished (or terminated) in the past. These cases are ideally both successful and terminated, as this will provide insight into key success factors for successful product development within the Business Incubator and main points of attention. These findings can be compared to the overall structured model (i.e. activities, assessment factors, decision-making roles), which would yield a conclusion of the applicability of the current model, taking in mind the key success factors and the point of attention.

Another approach for the validation of the model is to determine the validity of the phases pre-phase zero and phase one. As indicated earlier, phase zero was the only phase that is tested in this research. It has yielded promising results, though still several elements were missing in order to gain a complete understanding of the project (see section 6.4). The same approach should be taken to test the validity of the other phases with cases that may be positioned into these phases. The model should also be validated in terms of its ease of use for the employees who need to use it to proceed through the Feasibility phase. Therefore, it is recommended to stimulate the employees with the executing role to position their current cases into the model, after which a survey should be sent in order to determine the ease of use of the model and the added value of the model compared to the method the employees used before.

CONCLUSION

During this thesis work, a structured model for the fuzzy front end was presented, based on existing models from literature and interviews conducted at the DSM Innovation Center. The Business Incubator was the host of this thesis work and through this work, has gained insight into a way of structuring its fuzzy front end in order to reduce uncertainty and increase the probability of success of its running and future projects.

In conclusion of this research, the research questions posed in chapter 2 are answered. The main research question that has led the progress of the research presented in this thesis, was:

"In what way can the fuzzy front end for disruptive biotechnological innovations be structured while highlighting the relative importance of assessment factors for each phase?"

The answer for the main research question can only be provided after answering the sub-questions supporting this main research question. These sub-questions are answered below.

1. Which models are currently proposed for the fuzzy front end?

By performing a literature study, a wide variety of fuzzy front end models were obtained, which ranged from stage-gate to holistic models. The most prominent of these models were the stage-gate model designed by Cooper, the phase model proposed by Khurana & Rosenthal and the holistic model presented by Koen et al. Next to their own specific advantages and disadvantages, these models had two common points of attention that were addressed through the thesis work performed. First, no decision-making roles were assigned in any of these models, while DSM was in need of a clear overview in order to structure its own process. Second, the authors have not provided detailed insight into the activities involved in each phase or stage of their models; especially details on the type of information that was needed for proceeding towards a decision at the end of each phase were lacking.

2. What requirements are important to consider in the fuzzy front end?

A literature study has yielded an extensive list of assessment factors, which serve as types of information needed in order to assess the feasibility of innovations. Moreover, success factors were found that indicated the ingredients for success for the fuzzy front end as well as new product development as a whole. The combined insights from the current fuzzy front end models, the assessment factors and the success factors have yielded that three aspects needed to be taken into account for setting the requirements: uncertainty reduction, effectiveness and efficiency. These aspects translated into the following requirements:

- Uncertainty reduction in both market and technology
- Strategy alignment
- Decision-making roles division
- Ease of use
- Flexibility
- Applicability at DSM

3. How is the current decision-making process in the fuzzy front end organized for disruptive innovations at DSM?

After conducting a total of 7 interviews with internal experts at the DSM Innovation Center, two major findings were obtained that were of influence on the structuring of the fuzzy front end. First of all, within the Business Incubator two types of methodologies were used simultaneously for the assessment of innovations in the Incubator's portfolio. On the one hand, a stage-gate approach was used through the PMP framework, where the Feasibility phase was indicated to be the crucial and most-debated phase in this approach in terms of best practice. On the other hand, 'venture-thinking' was stimulated by the utilization of the Bell-Mason framework, which focused on the creation of corporate ventures. The interviewees have indicated that an integration of these two different approaches was needed to gain a complete picture of the deliverables required during the fuzzy front end.

Second, insight was provided into the decision-making roles maintained within the Innovation Center and the bases on which decisions were made. One major observation was that the employees who had a supporting role in the decision-making process indicated the process to be anything but rational and completely based on gut feeling, psychology and politics. In contrast, the decision-makers took pride in the current process being rational, while trusting on intuition obtained from years of experience in the organization. Moreover, the decision-making roles for the parties involved in the decision-making process could be assigned, as presented in Table 9.

The implications of these findings for the structuring of the model were that the model needed to have a rational basis on which decision were based. The involvement of intuition cannot be averted completely and should be applauded, but it should not be the sole basis for decision-making. Furthermore, the current decision-making roles can be implemented into the model once it is yielded.

Combining the insights from sub-question 1, 2 and 3 have yielded the structured fuzzy front end model, which could be further extended by addition of assessment factors.

4. What assessment factors are important for each phase of the fuzzy front end at DSM?

Through a panel study with innovation management experts at several DSM business groups, a list of factors was obtained for each phase of the structured fuzzy front end model. Based on the responses from the interviews held for the decision-making process, the assumption was made that the level of detail increases while moving further through the fuzzy front end. Therefore, the panel study was constructed in such a way, that the amount of assessment factors increased while moving through each phase of the structured model.

For each phase, a list of most important assessment factors was obtained (Figure 15). The obtained assessment factors were assessed on their relative importance in each phase of the proposed model. The opinions of the panel members were widely spread, which indicated that the fuzzy nature of this stage of development is mainly explained by personal beliefs. The type of innovation involved did not explain the wide spread, as within 'blue box' and 'red box' innovations, the panel members still disagreed. The influence of the organizational level or decision-making role on the significance of these differences could also not be determined to be the source, due to the large spread in opinions. However, these results have indicated that the importance of assessment factors most likely depends strongly on the personal opinion of the individual instead of the position this individual takes in the organization. This implicates that intuition is an intrinsic part of the fuzzy front end, which is not easily reduced in the decision-making process. The limited number of employees involved in these innovation processes makes further research by extending the panel difficult.

5. To what extent can DSM learn from the structured fuzzy front end and the assessment factors in each phase?

The proposed model including the assessment factors for each phase was tested by application of a currently running case at the Business Incubator at the time of writing. This case was positioned into phase zero of the model, where a feasibility study is performed regarding the case. The assessment factors have proven useful in structuring the methodology used, as the factors provided a clear indication of the information that was needed corresponding to the appropriate methods used to obtain this information. By using the model, the activities have also become more focused.

Still, lacking elements could be identified while validating this particular phase of the model, which were:

- The lack of assigned weighting to the factors, which was the result of the wide spread of opinions in the panel study and the interviewees from the interviews indicating that the complete picture was most important;
- The timing for market introduction and development in order to form a strategy on being the first mover or first/early follower;
- A distinction between different market segments in terms of niche applications and large-scale applications, which is not highlighted by the identified assessment factors;
- The newness of the innovation needs to be assessed based on market newness, technological newness and product newness, as indicated by the interviewees. However, the panel study has yielded only market newness and technological newness to be important, thus the newness of the innovation can only be assessed on these two axes.

Considering the evaluation of the model according to the requirements set in sub-question 2, the model was found to comply with the uncertainty reduction, the strategy alignment, ease of use and the applicability to DSM. The allocation of decision-making roles could not be tested due to the limited scope of the case presented in this thesis. The same holds for the flexibility of the model.

6. What are the recommendations for other organizations in structuring the fuzzy front end?

Next to the lessons learned from the case application in the model, general considerations were also discussed, which other organizations can take into account when structuring their own fuzzy front end process. The most important concern of the proposed model is the generalizability to other organizations, as it is strongly influenced by the organizational structure and culture at DSM. Within the different business groups in DSM, the model is generalizable. Considering other organizations, this thesis has presented a method of structuring the fuzzy front end, based on a template provided by the combination of different approaches from literature.

Other recommendations consider the sample size taken for the panel study and the validation of the model itself. For the panel study, it is recommended to plan a plenary discussion after each round conducted, while presenting the results from the previous round. By doing so, the probability of reaching a consensus through discussion is increased. In terms of the model validation, an analysis should be performed with multiple cases from the past in order to determine key success factors and points of attention for the organization. Moreover, a cross-case analysis of running cases will provide insight into the effectiveness of the model as a whole, as pre-phase zero and phase one still need to be validated.

Having answered the sub-questions, an answer to the main research question can be formulated:

"In what way can the fuzzy front end for disruptive biotechnological innovations be structured while highlighting the relative importance of assessment factors for each phase?"

The fuzzy front end for disruptive innovations can be structured through combination of different models obtained by literature (i.e. stage-gate model, phase model and holistic model), while integrating the resulting structured model with decision-making roles specific for the organization where the structuring takes place. Moreover, assessment factors defined by literature can be assigned to each phase of the structured model, while implementing experts' opinions on the relative importance of these factors. The model presented in this thesis is of an exploratory nature and still needs further research in order to optimize the decision-making based on the model. However, the model already encourages a structured way of proceeding through the fuzzy front end, which reduces the uncertainties involved in high-tech industries concerning the market and technological aspects.

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