A New Journey from Flower to Vase

Supply chain & digital system design for an automated vending business concept

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by

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in partial fulfilment of the requirements for the degree of

Master of Science
in Complex Systems Engineering & Management

at the Faculty of Technology, Policy and Management of the Delft University of Technology,
to be defended publicly on Wednesday May 15, 2024 at 11:00 AM.

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TU Delft

Preface

Well, here it is. My finished thesis project report. It has been some time since I started on this noble endeavour to achieve my degree at Delft University of Technology, and I kept thinking about this quote I read as a child:

The most instructive path is the path on which one stumbles.

Eastern wisdom found on a bottle of Conimex Ketjap Manis

I can definitely say that I learned a lot during my studies, both on a professional as well as a personal field. When I took the decision to switch from Aerospace Engineering to the faculty of Technology, Policy and Management, it felt like a gamble to see whether it would be a match. In hindsight, I should have made that decision far earlier. The study programme of TPM and CoSEM fits my preferences so much better that I am glad that I decided to go along with it.

When reflecting on this thesis project, I really liked working on a broad supply chain strategy. Compared to my previous experience relating to detailed design of small parts of a chain (warehousing), this thesis has provided me with a more holistic view of the field of supply chain management. Especially with the case that this study is based on, it allowed me to freely discover a novel industry (the floriculture and greenhouse sector) with little bias. I think that supply chain management and strategies are of great importance for the future and I hope to contribute to a similar project at a later stage.

From the educational perspective, this thesis has been a journey departing from some of the more rigid methods I learned during my CoSEM masters. With a background in Aerospace Engineering, the courses at this masters program did not initially seem that research-focused to me. However, in hindsight I think that virtually all meetings with my supervisor Marcel Ludema included some part of him reminding me that I was performing a design study and not a research project. I really learned a lot about this. As an example, the approach for requirements engineering that was taught in the CoSEM program turned out to be far too formal to be useful in such a project. I think it is interesting that I only noticed this during my thesis project and am interested to learn how this experience will develop later on during my career.

With respect to the unified supply chain business, I hope that Ton Kester's vision can find fertile ground within a short period. As a complete outsider to the floriculture industry as well as to Het Westland, I am very positive about the experiences I had with all with whom I had the pleasure speaking. I think all are very passionate about their products and fully understand their (sometimes strong) opinions about future plans for the sector. I hope that an innovative sector like this has a future in our country and hope that De Bloemistenkwekerij can provide a part of the solution in the future.

I would like to use this space to thank Priva and especially Jan Westra and Ton Kester for offering me the opportunity to join this project and be a part of the development. Robert Ossevoort and René Kester for the advice, interviews and feedback based on their extensive experience in the floriculture sector. Thanks to Marcel Ludema and Mark de Reuver for the invaluable advice and guidance given in directing me towards completion of this thesis project. Your guardrails helped me approach this in a scientific manner. Credit is also due to Jan Willem Barends, who took the gamble on ”the oddball guy who seemed smart” and thus introduced me into the world of logistics and supply chains.

Mick, thanks for our combined struggle at 2WI. Many other friends and family I will not list here who told me I could do this, you know who you are, your support will not be forgotten. Dad, mom, you can finally stop worrying. Yuki, thanks for the hugs and fun play times. We are going to take so many walks together! And finally, last but absolutely not least, Dora. Thanks for being there to slap me back to reality when necessary, to support me when necessary and for all the help provided. I could not have done this without you.

I hope that you will enjoy reading my thesis report!

Robbert de Keijzer
Delft, April 2024

Summary

The floriculture industry is an important sector in the Netherlands, both in economic and societal importance. It plays a leading role in the world market with especially the auction system surrounding RoyalFloraHolland guiding prices globally. The existing system has provided the Netherlands with significant benefits both directly and indirectly, and the industry is surrounded by a network of facilitators like distribution networks and breeders.
The status quo however faces several challenges, of which the production costs in a traditional greenhouse location is a main issue challenged by cheaper production in developing markets. Next to this, a shift towards more sustainable and local production is desired. A potential approach to overcome these challenges is by "unifying the supply chain". In such a business model, growers are directly connected to customers. This would provide the consumer with higher quality, fresher flowers and place a larger part of the value chain with the growers. A self-managed unified supply chain allows for a more data-driven business approach where customer demand forecasting is used to determine production quantities.
In such a business concept, a working relationship needs to be established between the physical operations in the supply chain providing flowers to customers and a system that coordinates and controls the flow of goods in the supply chain in a data-driven manner. This working relationship can be based in a digital system, consisting of software components and datasets connected to provide the requested capabilities. The business concept would therefore require both physical as well as digital operations to be performed simultaneously.
Priva, an expert company based in De Lier in the Netherlands that specialises in smart horticulture solutions, proposed a solution where a novel production location is combined with automated vending points to sell the flowers. No reports have been found on a similar scale or market conditions. As such, it is of interest to investigate the feasibility of a business concept based on a unified supply chain to market to meet the challenges facing the floriculture market in the Netherlands.
To investigate this feasibility, a preliminary qualitative design has to be made for the supply chain of such a business concept. This thesis will perform such a design study using the proposal made by Priva as a foundation. This study would need to design both the physical operations in the supply chain as well as the digital systems supporting the processes. This thesis has worked with the following design objective:

> *Develop a design for both the physical operations as well as the supporting digital systems for a unified supply chain that is feasible to implement by a starting floriculture business concept using automated vending points.*

A feasible design must provide future-proof operations by unifying all activities across the supply chain from production to sales. In this way, the added value along the chain can remain within the business model, allowing for a better result for both the customer and company. The check for feasibility of the approach can therefore be a building block for the floriculture sector to combat the challenges facing them. The business model could be an example for later adoption for both other parties in the floriculture business as well as for other industries facing similar challenges.
In this thesis project, the design objective is contextualised based on an exploration of the conditions where the designed system would operate. Based on this contextualised problem, a concept for the unified supply chain and a design space can be established. In this design space, alternatives were created for the physical operations in the supply chain, followed by a digital design of the coordination platform. The performance of the resulting design alternatives is then evaluated. Finally, the design is demonstrated by simulating the flower journey and evaluated in a workshop with clients.
The floriculture market is based around the production and sale of fresh cut flowers and ornamentals. These products all have long lead times in production due to growth times, and sometimes seasonal availability. Production in the Netherlands is centered in greenhouses. The resulting products share their difficulties in shelf stability, requiring environmentally controlled storage to prevent loss of quality

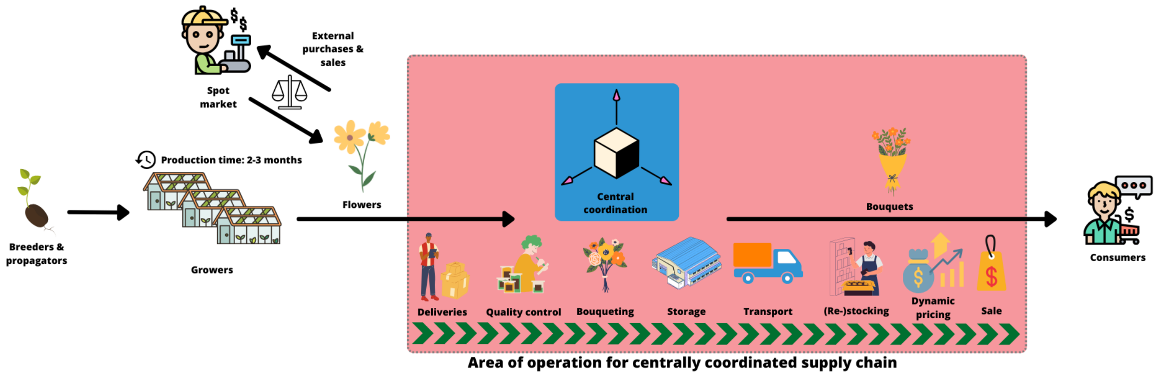

Figure 1: A rich picture detailing the flower journey in the proposed situation.

and value. The market itself is matured and highly dynamic, with a shift in consumer trends to amongst others sustainability and local production. Three main sales outlets exist: specialist shops, big box stores and e-commerce. In the Netherlands, a central role in the market and thus in supply chains is taken by the interactions between the auction system and wholesale traders. Their role as intermediary in most supply chains limits the bargaining power of other actors in the system.

Based on this context, a rich picture detailing the flower journey for the proposed unified model was created (figure 1). In this new situation, a unified supply chain from growers to consumers is depicted by following eight processes. For these processes, first of all requirements and constraints were created. They were then expanded into functional designs using functional flow block diagrams. The functions for these processes were matched with the requirements in a function-requirement matrix.

The actual design of the business model was performed in two steps: physical and digital. The physical design of the supply chain was chosen to be leading in the design methodology. For the physical operations in the supply chain, a morphological chart was created to explore different options that each function can be fulfilled. These options were then ranked using an adapted performance ranking method based on the SCOR method, a model that helps analysing supply chain processes. For all design alternatives, a level 2 SCOR mapping including thread diagrams was created.

Based on the physical design, the requirements for the underlying digital systems providing the function of a central coordination system were created using Enterprise Architecture modelling in three levels: business processes, application services and application components. All design alternatives were qualitatively evaluated with these method, comparing them based on complexity, required enablers and added value for the supply chain of the digital system.

The design study resulted in four alternatives:

- **Alternative 1: keep it short and simple:** this design prioritises simplicity throughout the supply chain, aiming to provide a predictable and straightforward journey for flowers from harvest up to the customer. In this approach, the focus shifts away from seeking high levels of control over the supply chain to minimising operational complexity. The supply chain operates on a make-to-stock basis. The digital system in this design is also of low complexity, utilising off-the-shelf software components and lacking any data requirements. However, a drawback of this approach is that it does not generate data, thus limiting future improvement possibilities.
- **Alternative 2: centralised and unified operations:** in this alternative, the focus is on attaining maximum control over the supply chain by centralising all operations within it. Although this necessitates extensive planning and coordination, it provides a high-value product for the consumer. The supply chain operates on a make-to-order basis. The accompanying digital system is very complicated, resembling an ERP software system, with numerous connections and components. It heavily relies on data to enable accurate demand forecasting, making the system vulnerable to the performance of this forecast.
- **Alternative 3: leveraging the existing chain:** in this design alternative, the aim is to leverage the pre-existing world-class logistical network and support infrastructure of the floriculture industry in the Netherlands. Consequently, some control of the supply chain is delegated to external partners. This design supports both make-to-stock (3A) and make-to-order (3B) operations. The as-

sociated digital system is relatively simple due to reduced central control requirements. However, integrating this system with those of external partners may introduce complexities. If implemented effectively, this integration could provide value for both the company and its partners.

- **Alternative 4: preparing for growth:** this design approach lays the groundwork for future complexity while starting with a simplified foundation. It aims to configure the supply chain similarly to alternative 2, enabling growth in that direction while deferring impactful decisions. This flexible design can accommodate both make-to-stock (4A) and make-to-order (4B) operations, depending on initial complexity. Although the digital system design comprises multiple components, each is of low complexity, reducing the dependency of the overall supply chain performance on the digital system's performance. The design also facilitates data collection for future system improvement, with data utilisation currently restricted to minimise complexities. However, the digital system's added value is currently limited due to simplifications in this stage.

The performance of various design options was assessed through a multiple-criteria decision analysis (MCDA). They were also compared against constraints, requirements, and SWOT (strengths, weaknesses, opportunities, threats) analyses were made. Using these, alternative 4, with a make-to-stock approach, ended up to be the best alternative.
A demonstration of the physical supply chain design was conducted through a simulation of the flower journey. Subsequently, these designs underwent evaluation during a client workshop, which confirmed the feasibility of all options. No clear winning alternative came out of the rating performed in this workshop.
The study resulted in four evaluated design alternatives suitable for implementing a unified supply chain in the floriculture sector for a business model utilising automated vending points. Within these options, alternative 4 stands out as the most advisable option for feasible implementation. The approach based on a unified supply chain is thus shown to be a feasible option to meet the challenges facing the floriculture market. It represents a novel option that can be used combining data-driven approaches to supply chains with centralised physical operations and automated vending points.
Priva can use the advised alternative as a building block in the development of their proposal, along with the production location. Whilst this alternative does not directly fulfill their envisioned level of coordination, it provides a basis for growth towards their ideal. Other actors in the floriculture sector both in and outside the Netherlands can use the approach to capture a segment of the consumer market. Their individual circumstances may require adaptations to the design, but since this project has shown the feasibility of creating a business model from scratch, leveraging existing experience and processes will most likely aid in feasibility of deployment. For comparable industries, physical supply chain designs may undergo slight adjustments to align with their production needs. The part of the physical design between production and automated vending points can be more easily applied to other industries. Moreover, digital systems design is versatile across product types, thus fewer adaptations have to be made to make the design suitable for comparable industries.

Contents

1 Introduction

The Netherlands plays an important role in the international floriculture business. It has been identified as one of the top ten sectors within the country (Ministerie van Economische Zaken en Klimaat, 2023), which emphasises both the economic and societal importance of the sector. The direct and indirect contributions of the sector provide around 3% of the gross domestic product and just short of 5% of both the export and the national R&D expenses (CBS & Wageningen Economic Research, 2020). Whilst the international floriculture market consists of many different entities, countries and actors, the Dutch market is guiding for the pricing of its goods. The auction system in the floriculture sector, managed by Royal FloraHolland, results in a price point that is used globally for business transactions (Melese & Whitfield, 2023). These auctions are the largest marketplaces for cut flowers in the world and provide the Netherlands with a firm foundation for the thriving floriculture business.
However, the established Dutch floriculture sector is facing several challenges. First of all, local producers in particular are threatened by upcoming developing markets with low-cost production like Kenya, Ecuador and Ethiopia which have access to both cheaper labour as well as cheaper production due to differing climate conditions. Additionally, consumer and legislative pressures in the Netherlands command a shift towards more sustainable adaptations, as the Dutch floriculture industry uses large greenhouse complexes that can strain the environment. This is particularly relevant for greenhouses that rely on natural gas for climate control. Finally, land usage restrictions, lack of available plots as well as labour shortages restrict the future growth of the floriculture industry within the Netherlands (Buitenhof, 2024). As a response to these challenges, the Dutch floriculture sector aims to reposition themselves in order to provide a future-proof business model.

1.1. A unified supply chain

One approach to overcome these challenges is by ”unifying the supply chain”: instead of growers producing flowers for sale on the auction to wholesalers, the aim is to predict consumer demand to be able to produce only the required variety of flowers and directly sell to consumers. The removal of intermediaries in such a system would provide the consumer with higher quality, fresher flowers due to the shortened supply chain whilst placing a larger part of the value chain with the growers.
Such a concept of a unified supply chain could be an interesting proposition for the market and the challenges it faces. The Dutch situation shows a highly developed push market where each actor has little bargaining power. Due to the lack of upstream data sharing in the supply chain, insufficient incentives are created to deviate from the established course. This results in a sector that is generally regarded as risk-averse and conservative. Growers struggle with the upfront investment costs at propagators that they must balance with a sufficiently high price point at the auction to make their investment worthwhile. This price point is also challenged by the high competition in both the domestic and international market. This causes them to choose for proven flower types as the auction price for that type of flower is more predictable. As a result, breeders struggle with selling their innovative product lines to growers as they choose for proven products. This prevents innovation along the cluster and limits the amount of available choices for the consumer later on.

From a consumer perspective, it is desirable to buy flowers that are as fresh as possible, have a traceable origin and are produced sustainably and/or locally. The current chain with multiple intermediaries (transport to auction, auction, transport from auction, wholesaler) lengthens the time it takes from grower to consumer, even more when considering delaying tactics employed by wholesalers to get a better price point. The flow of flowers with different origins into the auction and later spread towards consumers also limits the traceability of bouquets. This prevents consumer from acting upon preferences on sustainability or local production.
Such a unified supply chain would require the grower to be able to sell their own flowers and predict the demand such that production and sales can be matched as much as possible. This effectively turns this concept from a supply-driven market into a demand-driven market and thus reverses the information flow in the supply chain. Traditional floriculture businesses start with production and end with the consumer, but here consumer demand is the starting point for what to produce in the first place.

This creation of a self-managed unified sales channel opens the possibilities for the floriculture partners to be more creative and take more risk in their growing strategies. This would be more difficult to achieve under normal market circumstances as the risk-aversion along the supply chain prevents new concepts from surfacing easily.
Additionally, combining data from both production and sales processes allows for a more data-driven business approach. This includes using customer demand forecasting in order to prevent surpluses which increases margins as well as sustainability.
Such a system would not only allow the growers to capture a larger share of the value chain, but would also be more beneficial to breeders and consumers. For breeders, a system with guaranteed buyers can be an attractive partner for trial runs of their novel product lines. The reduction of demand uncertainty will make this system better adapted to take the risk of a novel line and it is capable of providing market performance data directly to the breeders. For consumers, it would provide fresh flowers with a short supply chain. They can thus be informed about what flower was produced where locally and also on average receive their cut flowers with higher freshness due to the shorter chain.
Last but not least, the removal of intermediaries places a significantly larger part of the value chain with the growers, allowing more competitive pricing or higher investments in research and development programs.

On the interface between both operations a working relationship needs to be established in which, amongst others, data about demand forecasts is fed to growers which in turn provide the sales channel with a stable and affordable stream of products. As such, some sort of a system that is able to provide this coordination capability for the unified supply chain is necessary in the solution. Such a coordination system would have to be a digital system to be able to handle large amounts of data. This digital system would consist of some software components and datasets that are connected in a way that provides the requested capabilities. The inclusion of digital systems in supply chain management is known to create significant and sustained performance gains (Rai et al., 2006). Supply chain analytics by means of big data business analytics can be a strategic asset for enterprises (re-)defining their supply chain strategy and operations (Wang et al., 2016).
Furthermore, the concept requires a different sales channel for the produced goods that complements the intended use of demand forecasting by easily adapting to changing customer demands. Such a channel would need to be able to be controlled directly by the company to remain a unified supply chain up to sales to consumers. As such, either self-operated points-of-sale or partnerships with existing sellers need to be included in the system.

1.1.1. A proposal by Priva

Such an approach is currently being explored by Priva, which is an expert company based in De Lier in The Netherlands that specialises in smart horticulture and building management solutions (Priva, 2023). The business concept proposed by Priva aims to bring together key actors to kick-start the creation of a novel business concept to provide a new direction for the sector. It concerns the creation of a modular greenhouse that also functions as a technology incubator. The concept proposed by Priva combines this internal production location with using automated vending points to sell the flowers. This way, the number of points-of-sale can easily be changed and the locations are less rigid compared to traditional brick-and-mortar stores. Moreover, the usage of automated vending solutions keeps the brand and business centralised around their hub greenhouse. Finally, the difficult labour market in the Netherlands also argues for a solution that does not require as many employees.

1.2. State-of-the-art

No reports have been found on a similar concept within the Netherlands. In Germany, where the floriculture market is significantly less saturated compared to the Dutch market, more unified supply chains do exist (Drechsler & Holzapfel, 2023). such an application would not be viable on the saturated Dutch market due to price competition from other growers and specialist retailers. Once a grower starts producing small quantities of different flowers, they lose their economy of scale. The only way for such a grower to remain competitive in the entire market is to capture a larger part of the value chain and be able to bring produce directly to market. In this way, the extra production costs can be offset by the reduced costs of intermediaries and their respective profit margins. Moreover, these supply chains are not known to incorporate data in their planning operations on a high level.
The concept may provide benefits for consumers as well due to shifting trends towards locality and traceability (Gabellini & Scaramuzzi, 2022). These consumer demands are currently not met since the complex multi-step supply chains limit traceability and the global functionality of the Royal FloraHolland auction as an import-export hub reduces the share of local varieties in the Dutch market.

Some small-scale adoptions of vending machines and automated stores already exist in the Netherlands. For example, *Oogst* is a concept combining locally created products into a self-service store for fresh groceries, currently operating in three municipalities (Lansbergen, 2022). Unlike the proposed concept, Oogst does not incorporate a unified supply chain but buys produce from outside suppliers, which eliminates the opportunity for a similar kind of synchronisation in the supply chain. *De Mosselkwekerij* (Yerseke, the Netherlands) operates a vending machine where fresh mussels and clams can be purchased (De Mosselkwekerij, 2024). This company however only sells through one machine as an addition to their manned shop, which is located close to their main place of operations. Finally, for comparison some growers operate vending machines with fresh flowers as well. *FreshVendi* for example operates six vending machines selling roses and tulips next to large DIY stores and garden centres (FreshVendi, 2021). These sales however are not the main outlets for the production of the suppliers: FreshVendi operates more like a surplus channel comparable to more low-tech carts along the road where flowers can be bought directly from the grower.

1.2.1. Knowledge gap

The increasing adoption of data-driven business models across many industries suggests a widespread desire of businesses to transform their business approach from reactive to proactive by leveraging the use of data. The concept of an unified supply chain solution that includes both production and sales within one proposition could thus be of interest to businesses in the field of supply chain as a whole. Specifically in the floriculture sector, no instance has been found in which such an approach is explored on a large-scale market. The wish of the Dutch floriculture sector to implement changes in the face of aforementioned challenges provides an exciting opportunity to further explore this concept. Successfully implemented, this design could strengthen the sector's existing foundation even more and at the same time ensure that *"Societal challenges can be met whilst improving the economic power of the sector."* (Topsector Tuinbouw & Uitgangsmaterialen, 2023)

1.3. Thesis aim

To arrive at the potential solution of a unified supply chain, a well-managed set of operations must be designed. A design of such a supply chain helps identify weaknesses and strengths of the proposed concept and therefore provides a necessary evaluation towards later success. The challenge of creating this design will be the focus of this thesis project.
To accomplish this goal, this thesis will have the following aim:

> *The challenges facing the floriculture market in The Netherlands necessitate the investigation of new business models. A unified supply chain binding production locations directly to consumers could be one of those solutions. This thesis aims to investigate the feasibility of bringing such a solution to market.*

1.4. Design objective

In order to investigate the business potential of a unified supply chain operation in the floriculture business, a preliminary design of the supply chain must be investigated. The proposal that has been made by Priva will be expanded upon for this study, combining a challenging product with a unified supply chain. As this is a novel proposal requiring foundational work for the structuring of the business, a design study including a qualitative analysis of the alternatives was found to be most appropriate in this phase of the project. This can then later on be implemented in quantitative studies or actual business practice.

Such a design study would need to look at both the physical as well as the digital operations in the system. First of all, the physical systems are an indispensable part of getting flowers from harvest to customer. The physical operations design should therefore propose the steps that have to be made to ship the product along the supply chain. As this design study focuses on a business concept using automated vending points, this introduces a coordination problem between the different stages of the supply chain. The sourcing of flowers, the production of bouquets and the (re-)stocking of the vending points needs to be managed efficiently to prevent waste and provide value for both the consumer and the business. The balancing between these operations is the basis for the coordination problem. A proposed inclusion of a digital system linking the supply chain operations could provide a solution for this problem. Such a digital system would be based on software system(s) and data management that helps the business in coordinating the supply chain in the desired manner. The design of such a system should therefore also be included in this study, as it will interact heavily with the physical operations of the supply chain. The realisation and complexity of the digital system can then also be explored in this study.

Based on these considerations, the following main design goal is proposed:

> *Develop a design for both the physical operations as well as the supporting digital systems for a unified supply chain that is feasible to implement by a starting floriculture business concept using automated vending points.*

1.4.1. Relevance

The result of the design study will be a supply chain mapping combined with a digital systems design that will attempt to face the problem stated earlier. The study combines multiple methodologies in design science to come to an overarching solution for all specifics mentioned. It will attempt to place technologies like automated vending and digital systems within this specific context. The thesis project will be performed as part of the Complex Systems Engineering and Management MSc-program of Delft University of Technology. In this program, a focus is placed on the interactions of technology and innovations on existing institutions.

This supply chain design study is based on the initial proposal by Priva, which could function as an application of the unified supply chain in the floriculture sector. From their proposal, the interfaces where this design study operates within the real world are taken. On the start of the supply chain this interface of the system is inclusion of an internal production location besides external purchases. On the other side of the chain, their proposed automated vending points will be the sales outlet for the concept. Within these interfaces, the design space is left open for this study.

While the business model design will be focused on the Dutch floriculture specifically, the resulting design can also be a useful framework for other industries with similar challenges. Such an industry can for example be the sale of perishable foods like fresh produce or the distribution of other limited shelf-life consumer goods like certain pharmaceuticals. These industries can also encounter a complex interaction between production and demand forecasting, automated vending systems and perishable goods.

By completing this design objective, an answer to the goal set in the thesis aim will be found. It will create different design alternatives that can be evaluated on performance and therefore give a better indication of the feasibility of the solution of a unified supply chain. The design can therefore be a building block for the floriculture sector to combat the challenges facing them, as well as for other industries facing similar problems.

1.5. Thesis outline

This thesis report will describe the design process and result for the supply chain of the sales channel of a unified chain floriculture concept. To start, in chapter 2 a description of the methodology used for this thesis project will be given. Next, in chapter 3 the context in which the design operates will be researched and based on this, an analysis of the situation is made. This leads to a problem statement and a concept of an intervention in chapter 4 After this, a list of requirements will be developed to solve the problem. Based on these requirements, design alternatives for the supply chain will be developed and discussed in chapter 5. Following the operational design process, a design of the digital system required for the supply chain will be created in chapter 6 and this will again be discussed. In the following chapter 7 the design alternatives will be ranked for suitability. To finish the design process, chapter 8 is dedicated to how the results can be demonstrated and evaluated. Finally, some conclusions will be drawn about the resulting design in chapter 9.

2

Thesis project methodology

This chapter will detail the methods that will be used to perform the thesis project. Based on the design objective postulated in the previous chapter, a thesis flow is presented which will be followed for the design study that is used to achieve the objective. This thesis flow will be a break down of the main phases of the thesis project and the logical processes combining them. For these steps in this thesis flow, the thesis methods that will be employed will be described in the next section.

2.1. Thesis project flow

In the selection of the thesis project outline and flow, certain methods are chosen to achieve the objective of the project. The methodology of the design exercise is based on the approach described by (Johannesson & Perjons, 2021) which is partially based on earlier work by (Peffers et al., 2007). This framework describes a methodological approach to the steps that have to be taken in a design study, providing guidelines about tasks that must be completed and ways to interpret their results. This methodology is adapted for this project and presented in figure 2.1.
The steps in this framework and their accompanying chapters are explained below. The framework guidelines are converted to direct tasks related to the design study in this thesis project. The methods that are used to complete these stages will be explored in the next section.

Chapter 3: Setting the operational context of the design

This chapter investigates the context in which the proposed design will operate. First of all, the relevant factors for the supply chain like volume, geospatial spread of production and demand will be of interest, as well as specific issues like product handling, shelf life and seasonality. The existing logistics

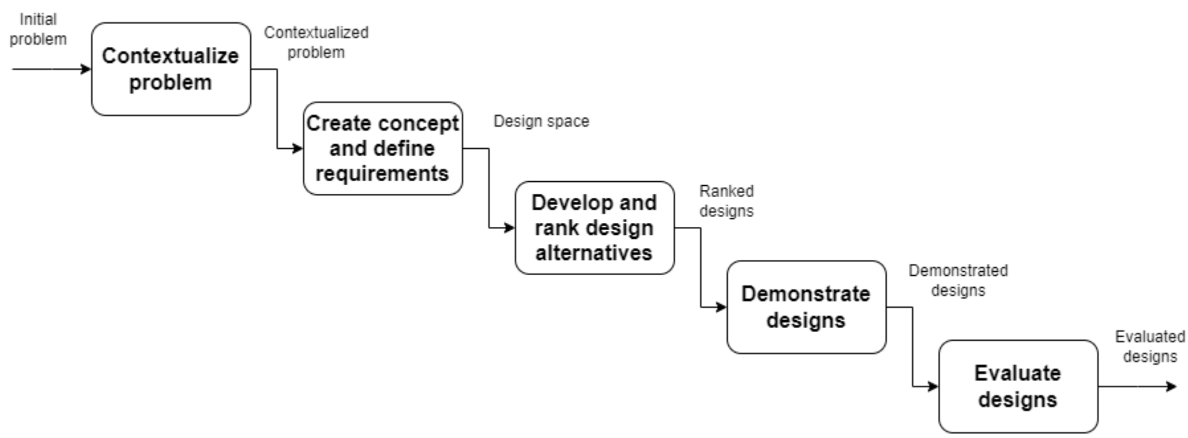

Figure 2.1: A method framework for design science research (adapted from (Johannesson & Perjons, 2021)).

systems in this industry and their relevance to the proposed solution will also be discussed. Part of the context setting in this stage of the thesis project will be a deeper investigation into the concept of a unified floriculture supply chain, as well as the impact of automated vending machines. Finally, an overview of key actors, values and needs will be made. This chapter completes the first box of the framework in figure 2.1 by providing a contextualized problem.

Chapter 4: Establishing the problem and converting it into a concept and requirements

Based on the information gathered about the context of the proposal, an updated problem statement can be made. Using this problem statement, a first concept for the supply chain design can be developed. By creating this conceptual representation of the supply chain, both the operational and digital systems that have to be designed later on can be better understood. The supply chain concept will also provide a foundation for the creation of requirements and constraints. This list of requirements and constraints will be based on the relevant parts of the supply chain investigated in the previous phase. With both a concept and a list of requirements and constraints, this chapter aims to result in a restricted design space and a clear goal for the design. This chapter would thus complete the second box of the framework in figure 2.1.

Chapter 5: Design of the physical supply chain

Here, the thesis will focus on design and development of different approaches for the supply chain of the business concept. These designs must adhere to the design space created by the requirements. The physical design of the supply chain is the leading part of the design work. Four alternatives will be developed for the physical supply chain in this phase, and of each a supply chain mapping will be made. This chapter is part of the development process of design alternatives, and thus partially complete the third box in figure 2.1.

Chapter 6: Digital systems design

Based on the design alternatives created for the physical supply chain operations in the previous chapter, a design will be created for the digital systems that are required to facilitate the supply chain activities. Next to this, the data requirements and generation activities will also be determined. The resulting digital systems design indicates the enhancement it can provide to the supply chain as well as its difficulty of implementation. The results of the four alternatives are then compared to each other. These digital designs will thus complete the development process of design alternatives in the third box in figure 2.1.

Chapter 7: Design performance rating

After the design alternatives have been created, this chapter rates the designs based on the chosen options. In this way, the most appropriate design can be determined and its performance will be evaluated. This result will then accomplish the main design goal: the development of a feasible supply chain design. These rated alternatives will thus finish the third box of the framework in figure 2.1.

Chapter 8: Design demonstration and evaluation

The design alternatives that were developed and rated in the previous chapter, will be simulated to demonstrate their performance. Next, the design will be communicated to stakeholders by means of a workshop where the resulting supply chain and digital systems design alternatives are presented and subsequently evaluated by gathering feedback from experts. This will result in an evaluated design recommendation with potential for future implementation. This chapter will thus complete box four and box five of the framework in figure 2.1.

2.2. Methods

Now that the thesis project flow is known, the methods that will be used to complete the different steps in the design study can be explained. These methods and the reasoning behind their selection will be discussed in this section for each chapter.

2.2.1. Chapter 3: Exploration of the context where the result of the design will operate

The first step of the project involves getting a better overview of the playing field that the new concept will operate in. This chapter will aid in exploring this phase and lead to a context for the problem that the design aims to solve. This phase starts with a literature study about the subject at hand to develop a firm theoretical and scientific understanding of the floriculture business and especially the Dutch market. This literature review will also help finding comparable problem situations and their respective proposed solutions. These experiences in different contexts can be translated to the situation at hand and aid in the exploration of the design space.

Besides a literature review into comparable methods, a deeper investigation is performed into the concept of a reversed floriculture supply chain to get a better grasp of what such a proposal might entail. For this, both literature about general unified supply chains can be interesting as well as literature about experiences with such a chain in the floriculture business with a different scope.

After the literature review and exploration of the concept, the operating context of the proposed intervention is investigated. (Johannesson & Perjons, 2021) note the relevance of positioning and justifying the problem within the context that it presents itself in. This section will also result in finding the root causes of the problem. To add to the understanding, some interviews have been performed with clients and an expert in floriculture logistics. These interviews will be with open questions in a semi-structured approach to explore the different facets of the concept. By keeping the questions open, unexpected consequences can be obtained from the interviewee without being influenced by the researcher's bias. The semi-structured approach aims to prepare the interview along the expected parts of the problem, with freedom to investigate functions in more detail when required. The interviews with the clients will be reflected with knowledge discovered in the literature study to limit the impact of their biases as well. The resulting context will be described in chapter 3.

2.2.2. Chapter 4: Establishing the problem and converting it into a concept and requirements

The context chapter will provide the basis for chapter 4, where the next step in the design method framework of figure 2.1 will be performed. Based on the context, the final step to arrive at an explicated problem is to precisely define the problem at hand. Chapter 4 will be an analysis of the problem and its context and will result in a problem statement. To start with scoping the design space, a conceptual representation of the supply chain is created to aid in the understanding and structuring of the design space. To create such a concept, the rich picture methodology as described by (Checkland, 2000) will be employed. Rich pictures are a method from soft systems methodology where complex interactions can be visualized to improve understanding of the concept. As the proposed unified supply chain can be considered such a system of complex interactions, the rich picture method can help in creating a structure that can be used for the creation of requirements and constraints.

The rich picture that has been created, combined with active communication with the client, can be converted into a list of constraints and requirements to delimit the design space. As is described by (Bennaceur et al., 2000), four techniques can be used in this process to create requirements: elicitation, modelling & analysis, assurance, and management & evolution. For this thesis, elicitation will be the main technique employed. As a part of this technique, data gathering has been performed in an earlier stage and together with the client, brainstorming can be performed to create further requirements. The requirements will be modelled using three types: constraints, functional requirements and non-functional requirements.

2.2.3. Chapter 5: Design of the physical supply chain

The next phase in the method framework of Johannesson and Perjons is the development of the design and the ranking of the alternatives. The first step is the development of design alternatives for the physical operations in the supply chain. For this, the requirements and the rich picture concept are converted into a functional design using functional flow block diagrams (FFBD). An FFBD is a method based on Unified Modeling Language (UML) that represents the different steps in a process in a structured way. It applies the methodology of UML stemming from software development to other fields of interest, including physical processes. FFBDs are a powerful tool in systems engineering to represent

	FLR	GSCF	SASC	WCL	ASLOG	EVALOG	AFNOR	SCM/SME	BSC	SPM	ABC	SCOR	SCALE	APICS	ECR	EFQM
Decision level																
	✓	✓	✓	✓			✓	✓	✓	✓			✓	✓	✓	✓
Tactical level	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓
Operational level	✓	✓			✓	✓					✓	✓		✓		
Type of flows																
Physical flow		✓	✓	✓	✓	✓	✓	✓				✓	✓	✓	✓	✓
Informational flow	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓
Financial flow				✓			✓		✓	✓	✓	✓	✓			
Level of supply chain maturity																
Intra-organisational	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Inter-organisational		✓	✓	✓		✓	✓	✓		✓	✓	✓			✓	
Extended inter-organisational										✓		✓	✓		✓	
Multi-chain										✓		✓				
Societal							✓	✓	✓			✓	✓			✓
Type of bench-marking																
Internal	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
External				✓		✓				✓		✓	✓		✓	
Contextualisation																
SME								✓								
Retailer															✓	
Industry						✓								✓	✓	
Service																
All sectors	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓			✓
Quality factors				✓			✓					✓				✓
Human capital				✓					✓			✓				✓
Sustainability							✓	✓	✓			✓		✓		✓

Figure 2.2: An evaluation of the focus of different supply chain performance measurement models. Taken from (Estampe et al., 2013).

the system interactions (Bock, 2003). The FFBDs will provide a list of functions that have to be fulfilled, for which different design options can be chosen.

These design options are gathered into a morphological chart to structure the later design process (Pahl & Beitz, 1996). This chart will be filled with options that are widely used for the different functions within the broader supply chain sector for comparable processes. Alternatives were added to these options, which were discovered during the interviews and literature study performed in chapter 3. In this way, an expansive overview of the possibilities in the design space will be provided. These possibilities do however not come with a measurement of feasibility of implementation in this design project.

To review the morphological chart and determine the feasibility of implementation of design options, a performance rating study of these options is performed. For this, a supply chain performance analysis model is chosen, based on the selection process established by Estampe et al. (Estampe et al., 2013). They base their selection of appropriate supply chain performance analysis models on the maturity level of the analysis that will be performed. For this, the authors proposes five different levels:

1. **Intra-organisational:** focused on the own organisation and the interactions between functions.
2. **Inter-organisational:** including partnerships with different actors in the chain limited to suppliers and customers.
3. **Extended inter-organisational:** extending to contracting and an overall vision of value creation.
4. **Multi-chain:** expanding partnerships to entire chains of other actors and the pooling of resources and profit-sharing in the chain.
5. **Societal:** the integration of societal performance and including global value creation.

The intended design might include pooling of resources and profit-sharing with a dedicated production partner with its own supply chains. When comparing this to the models matrix in figure 2.2, the supply chain design will focus on both the internal supply chain but also its connections and partnerships with other actors. The design result can thus be placed on supply chain maturity level 4 (multi-chain) from (Estampe et al., 2013), which leaves SPM (Strategic Profit Model) (Stapleton et al., 2002) and SCOR (Supply Chain Operations Reference Model) (ASCM, 2022) as potential performance evaluation models. As SPM is focused towards financial drivers, this model is less suited for a qualitative study and therefore SCOR is selected as the most suitable performance measurement model.

The presence of metrics in SCOR will help in the decision-making process of the different alternatives and can therefore help in the decision-making process. A selection of the SCOR performance metrics will be used to evaluate the design options. The SCOR model performance metrics are intended to be applied to existing supply chains. Their scores are based on comparison to competitors and potential changes, with some metrics gaining a score in the range of parity/advantage/superior to those competing supply chain set-ups. As this design study intends to create a supply chain design for a novel concept, no easy comparison to existing methods can be made.

Therefore, the SCOR model performance cards will be adapted slightly to score compared to the other design options for the same functionality. This is done by comparing the performance of these options to each other based on their advantages and disadvantages. This comparison is based on internal logic of the design process: a qualitative assessment of the performance of the options is made, rooted in the context of the problem created earlier based on the interviews and literature study. A scoring using the Likert scale helps provide a qualitative assessment of individual design options in this design study whilst still employing the systematic approach of the SCOR model.

This performance study will result in a reviewed morphological chart where an initial degree of feasibility of the design options is now known. Four different design approaches will be theorised to convert the reviewed morphological chart into actual design alternatives. Together, these approaches intend to combine as many well-performing design options as possible in the reviewed morphological chart into a coherent whole. The supply chain design alternatives will be mapped on the first and second levels of the SCOR model, including the creation of a thread diagram.

2.2.4. Chapter 6: Digital systems design

Based on the physical design of the supply chain, designs can be made for the digital system required to support the supply chain. This will be performed using enterprise architecture modelling using Archi (The Open Group Standard, 2022). Enterprise architecture is "a coherent whole of principles, methods, and models that are used in the design and realisation of an enterprise's organisational structure, business processes, information systems, and infrastructure." (Lankhorst, 2005). It is a methodology created to provide a holistic view of the IT systems in the business enterprise. As the digital systems will be based on the business processes of the physical design alternatives, enterprise architecture can be applied to translate this into a preliminary design of the IT system. Archi is a software package that can be used to model digital systems in enterprise architecture, which will be done on three levels: business processes, application services and application components. This final layer of components can then be used for an informed discussion about the digital designs, amongst others based on the complexity and availability of the components required for the digital design.

2.2.5. Chapter 7: Design performance rating

Based on the metrics from the SCOR analysis, a multiple-criteria decision analysis (MCDA) will be employed to select the best scoring alternative (Belton & Stewart, 2002). In the MCDA the selected options from the morphological chart will be linked to their performance score cards. The MCDA will be expanded with categories to account for the impact of the digital design in the calculation of the analysis. Next to this, each design option in the morphological chart will be given an importance weighting, to achieve a more representative scoring. This will result in an internal assessment of the design alternatives and thus a first rating of the alternatives. Next to this assessment, a SWOT analysis (strengths, weaknesses, opportunities, threaths) of the alternatives will be made. The results of the MCDA and the SWOT analyses will then be compared to the list of requirements and constraints to determine for each alternative whether they provide an answer to the design objective.

2.2.6. Chapter 8: Design demonstration and evaluation

After the performance rating has demonstrated the capabilities of the designs, the next step in the methodology of (Johannesson & Perjons, 2021) is to demonstrate the capabilities of the design. In order to do so, the design alternatives will be simulated using rich pictures depicting the flower journey along the supply chain. These rich pictures will be based on the same methodology as the concept development rich pictures. The flower journey provides a demonstration of the design of the physical operations of the supply chain. The digital design is already simulated by the enterprise architecture models.

To evaluate the design, a design communication exercise will be performed for stakeholders where the design alternatives will be presented. After this, the designs will be rated using the same metrics as in the MCDA. The interactive workshop is intended to both communicate the resulting design and gather feedback about the result. The results of this process is described in chapter 8.

3 Contextualising the design

This chapter will provide background information about the societal context of the design that will result from the thesis project. As was mentioned in the introduction, the design will aid in providing potential solutions for the future of the floriculture sector in the Netherlands and thus the current and future conditions of this sector will be described here. First of all, the product that is being investigated is discussed: fresh flowers. For this, both flower types and their usage in bouquets will be discussed. Second, the production stage in the sector will be explored. Here, used technologies and the resulting production process are explained. Some innovations in this sector are also explored. Next, the floriculture market is researched for the international market dynamics and, with a deeper focus, on the role of the Netherlands in this business environment. Thirdly, the logistics related to the earlier explored markets and production processes are elaborated. The activities along the supply chain for the entire market are discussed and some existing examples in the Netherlands are explored. Then, control models for this activity are discussed. To finish the chapter, methods to operate automated vending systems are discussed. Methods to forecast consumer demand are researched for both existing approaches as well as replenishment of these systems.

3.1. Expert and client interviews

As a part of the gathering of information for the context of the project, two clients and one industry expert were interviewed. All have gathered significant experience in the field of floriculture production, sales and management. They provided relevant information and insights into their respective fields which was used in the writing of this chapter. The interviewed experts and their experience are listed in table 3.1. T. Kester and dr. ir. J. Westra were chosen to be interviewed as clients, due to their involvement in the proposal that has been provided by Priva. Their interviews helped with providing information about why their proposal was suitable for solving the initial problem statement. However, their statements were not taken as a given due to the fact that clients are not independent experts. Therefore, the insights gathered from these interviews will be checked with those found in a literature study to provide the context that is independently written in this chapter. Finally, from the network of Priva, the expert in supply chain and logistics for agriculture products R. Ossevoort MSc was contacted and interviewed.

3.2. Floriculture products

The first section of this chapter is concerned with the product type that will be central to the new supply chain: plants and flowers. These products mainly consist of two categories: fresh cut flowers and ornamentals. The flowers are often sold bunched together in a bouquet, which is also discussed in this section.

Table 3.1: Expert and clients that were interviewed and their experience

Name	Experience
T. Kester	35 years as a grower of multiple plant types
	Former owner of multiple florists
Dr. Ir. J. Westra	27 years working at Priva
	12 years as strategic business developer
R. Ossevoort MSc	2 years as a director of multiple florists
	2 years as program manager Agri & Food Logistics at TKI DINALOG

3.2.1. Fresh cut flowers

The Netherlands has a long history with fresh cut flowers as ornamental products. The tulip is an internationally recognised symbol of the country, but also holds value for the citizens of Holland. Back in the 17th century already, interests in tulips soared to such heights that the first bubble in modern financial systems was created: tulip mania (Kindleberger & Aliber, 2008). Today, fresh cut flowers come in many varieties and types. In 2023, 23,333 types of flowers and plants were traded via the Royal FloraHolland auction, of which 11,469 were types of flowers (Royal FloraHolland, 2024).
A fresh cut flower is a product that is harvested by cutting off parts of a plant, most often the stem and the bulb. Afterwards, the flower can be transported and sold to end consumers for decorative purposes. Fresh cut flowers come in many types, with popular families including the rose, tulip, lily, chrysanthemum, gerbera and lisianthius. Within these flower families, many different variations have been created both for better growing as well as to reach new consumers. Due to the cutting of the flowers, these organic products have a shelf life limited to a maximum of a few weeks. They are also a relatively fragile product that easily attains cosmetic damage, which is unfortunate since the appearance is an important driver in consumer valuation.
Consumers value the decorative and therapeutic effect of fresh cut flowers. This drives their repeated consumption, both for private consumers as well as for the institutional segment. Consumers purchase flowers as a luxury good, and especially urban consumers are known to value flowers for greening their personal lives (Gabellini & Scaramuzzi, 2022). Evidence has been found that links plants and ornamentals in ”physiological, psychological, cognitive, and social well-being” (Hall & Knuth, 2020).

3.2.2. Bouquets

Fresh cut flowers are often processed into a bouquet, by binding them together and sometimes wrapping them in an ornamental packaging material. Bouquets add value to individual flowers by enhancing the appearance of the whole over the individual flowers. Bouquets also have societal value due to their usage in for example funerals and weddings, as well as gifting or romantic value for some people. After purchase, bouquets are placed in vases on water to preserve their quality.
Bouquets can be divided into three main types: mono, traditional and field. They are shown in figures 3.1a to 3.1c. A mono-bouquet is created by bunching together a multiple (often 5 or 10) of the same type of fresh cut flower. These bouquets are relatively simple and often bought for home decoration, not gifting. An important outlier here is the mono-bouquet of red roses traditionally given during Valentine’s day. A traditional bouquet is created by bunching different types of flowers together with ornamental branches and packaging material. Such a bouquet is most commonly gifted, due to its presentable look without a vase. Finally, the field bouquet is a more modern interpretation of the bouquet. This bouquet also consists of multiple different flowers, but is aimed to give a more wild look compared to the man-made look of a traditional bouquet. Field bouquets aim to represent what one would gather growing ”in the field” at that time, but often consist of a large variety of imported flowers. This occurs due to the fact that seasonality does not always provide blooming wild flowers at all locations.

3.2.3. Ornamentals

Another category often associated with fresh cut flowers is that of ornamentals: decorative plants that have not been cut before sale. Ornamentals are therefore in general a bit more lenient in product characteristics regarding environmental condition requirements and shelf life. Due to the fact that these plants have not been cut or uprooted, ornamentals are sold including soil and roots. This may come

(a) A mono-bouquet

(b) A traditional bouquet

(c) A field bouquet

Figure 3.1: The three main types of bouquets

in a simple plastic pot that can be discarded after replanting, up to a decorative vase that can be used as-is. The share of ornamentals compared to cut flowers is growing under younger generations as they see these living plants as a more sustainable alternative to repurchasing cut flowers after wilting (Gabellini & Scaramuzzi, 2022).
Ornamentals come in many shapes and sizes, as well as many price ranges. Cacti and succulents are relatively small and sturdy, making them easy to handle. Orchids however are more delicate and sensitive to environmental conditions. Larger house plants like strelitzias and ferns, as well as garden plants, will not be considered in this thesis due to their difference in usage compared to fresh cut flowers. Smaller ornamentals however could be a viable alternative to include in a product range to provide for consumers.

3.3. Floriculture production

This section of the context chapter is dedicated to the production activity in the floriculture sector. First of all, the process itself is discussed. Next, technologies currently employed are investigated and finally some innovations that can help the production of fresh flowers.

3.3.1. Production process

The production process of a fresh flower starts with the selection of the type of flower that is going to be produced. For this purpose, breeders provide a portfolio of different types of bulbs or seeds that can later be grown into the actual flowers. Breeders stock both proven plants and attempt to improve their portfolio with new offerings in for example flower appearance or growth characteristics.
For most fresh flowers, the actual ordering by growers does not occur at breeders but at propagators. These actors produce starting material: small plants that are grown from seeds and cuttings that can be directly planted by the growers. These propagators provide uniformity in the starting material such that the plants that will be grown by the breeders will also grow more equally, providing for easier production and harvest.
The average growth time for fresh flowers is around 2 months. For this production process, two important factors divide the market: soil or hydroponic farming, and perennial or annual plants. The first factor describes the type of base that the producer can use to grow the plants. Whereas plants are most commonly known to grow in soil, the optimal conditions in greenhouses allow growers to substitute soil for other substrates like rockwool or clay granules. This method is not possible for all plants however. Hydroponic growing is relatively cheap and more easy to control than soil growing, but requires adequate installations for monitoring growth conditions (Savvas & Gruda, 2018).
Next, the plant type may differ in the seasonality of production. Flowers like tulips or gerberas are annual: they provide a single harvest and afterwards the plant must be uprooted and new starting material is required. Perennials like roses however can provide multiple harvests per plant and will not need to be replaced as often. An advantage of annual plants is that it allows for greater flexibility of the growing space: plant types can more easily be rotated or switched out. They do however require continuous investment in new starting material, compared to the lower investment in perennial starting material. However, these plants limit flexibility and require downtime in production when the plant is

not in harvest season. Some flowers deal with seasonality: they only grow during certain seasonal conditions and availability is thus limited outside of this season. By internationalising the supply chain, attempts have been made to provide year-round supply of these products due to differences in seasonal conditions around the globe.
During harvest, growers cut the flowers from their stems and gather them in bunches. These bunches are most commonly gathered in groups of 10 and bound with rubber bands around the stems. The fresh bunches are then placed in water and temporarily stored in cooled conditions to prevent quality decay before transport from the grower to a later location in the chain.

3.3.2. Technologies and innovations

Most of the floriculture production in The Netherlands is performed in greenhouses. In a greenhouse, artificial conditions can be created to promote the growth of plants that would otherwise not grow or provide less yield under the outdoor conditions. A principal condition in the greenhouse is heat: this can be provided by solar radiation, geothermal energy or fossil fuel-powered heaters. In the last case, the usage of fossil energy is a contributor to climate change and thus a challenge for the sustainability of the industry. Due to the large investments involved in the construction of adequate heating equipment, it is difficult for producers to switch to a different source causing them to remain locked-in to existing sources.
Besides heat, lighting and air conditioning are regarded as important environmental conditions in greenhouse production. For artificial lighting, recent innovations in LED technology allowed for cheaper running costs and more specific applications to become available. Most prominent here is the purple LED lighting which provides only the wave lengths that plants use to grow without wasting energy on other parts of the visual spectrum. Air conditioning focuses on the specific humidity and CO_2-levels to optimize growth as well (Ramin Shamshiri et al., 2018).
To support the growers in controlling and optimizing their production process, a large industry of companies, including Priva, specialised in installing complicated equipment for this purpose has been created in parallel with the growing industry. These companies focus on providing equipment for the grower to create optimal control over both environmental conditions as well as nutrient conditions for their plants. For this purpose, sensor technology within a wireless network or internet-of-things system is installed and employed to provide direct feedback to the grower. Other companies specialise in providing pest protection, with some using live insects and birds within greenhouses to complete the microclimate.
The greenhouses in the Netherlands are becoming more automated due to the increase in scale and the pressure on available labour. Automated systems include watering systems, transport rails and harvesting robots. The usage of these systems provides growers with a high upfront capital investment but lower operating costs, which can provide a competitive advantage.
Breeders of fresh flower types use genetic research to optimise their portfolio of seeds and bulbs to the expected market conditions. The flower types can be optimised to be of a novel colour or shape. It can also be used to improve growth characteristics like pest resistance, nutrient usage or length of harvest season. Genetic testing has significantly sped up the process of crossbreeding plants to create new species as the new seeds can easily be tested on desirable genes, whereas full growth cycles were necessary previously. Due to European law, only crossbreeding of flower types and species is allowed in the Netherlands whereas internationally, novel technologies like CRISPR-CAS that directly genetically modify plants are used as well. The breeders present their novel plants at a yearly show for growers to purchase, but encounter low adoption rates with on average less than 10% of the new product range being adopted.

3.4. The floriculture market

After investigating the production process, it is also relevant to provide context by observing the market in which the actors operate. This section will first look at market dynamics in general and then look in-depth at the role of the Netherlands in the floriculture market.

3.4.1. Floriculture market dynamics

The European floriculture market can be considered a matured market with both high-value domestic demand and a strong local production base (Gabellini & Scaramuzzi, 2022). Ornamentals like fresh flowers are the most dynamic market with the widest product range within the floriculture sector. Within this market, the Netherlands is a major producing country of both flowers and plants, with strong import links to low-cost production areas around the world like Kenya, Ethiopia, Colombia and Ecuador. The European market value is expected to grow approximately 20% up to 2027, but adaptation is also necessary to accommodate the impact of several changes in e.g. globalization, climate change and sustainability. Six important consumption trends were observed by the authors of (Gabellini & Scaramuzzi, 2022):

1. A preference of quality over price by consumers
2. A focus on sustainability and transparency of the supply chain
3. The purchase of ornamental products for their "socio-ecological and therapeutic functionality"
4. A preference for locally-grown and seasonal flowers
5. A growth in the valuation of customized services
6. The usage of omnichannel shopping opportunities

Besides the European consumer market, the continent also has a relevant institutional demand segment. Here, the private sector focuses on the added value of plants and flowers for their commercial spaces for both their personnel and customers. The public sector demand is concerned with the decoration and regrowth of both the urban and rural environment.
Due to the high value of demand and the high availability of supply, the European market is undergoing hypercompetition creating a rapidly and unpredictably changing environment. Companies have to adopt new market strategies to both cut costs to remain competitive to upcoming markets with low production costs like Kenya, as well as commit to sustainable business practices demanded by consumers. Research by Rabobank ((van Horen, 2017)) expects three types of outlets to become dominant in the coming years:

- **Specialist shops** currently capture around half of the market but their share is expected to decline due to consolidation and retirements in this sector.
- **Big box stores** like supermarkets and garden centre chains rely on low costs high volume economies of scale and are expected to keep their position due to their cost-price leadership.
- **E-commerce channels** are expected to grow significantly both due to direct sales to consumers as well as subscription models for fresh flowers. These channels may cut out traders if they manage to directly source from growers.

Cut plants are a difficult product to market: as a perishable good, they lose around 15% of their value every day after harvest and they have a shelf life of approximately two weeks under normal conditions. These characteristics are however not uniform between plant types and thus complicate the handling and operations when mixing different goods.
To further complicate the market dynamics, both demand and supply can expect to be influenced by uncertainties like weather and climate conditions, or consumer trends. This forces actors in the chain to rely on rush orders or sell-offs to prevent wastage. Due to the lengthy growth process in production, these fluxes cannot easily be adapted to on an individual level but are currently compensated by scale of the entire system to dampen impacts (Drechsler & Holzapfel, 2023).

3.4.2. The Netherlands and its role in the floriculture market

The value of the production chain of horticulture and starting material in the Netherlands reached €31,2 billion in 2022, with 23,700 companies working in this field employing 246,000 persons (Topsector Tuinbouw & Uitgangsmaterialen, 2023). As a Topsector and with the Greenports Holland, the Netherlands play a central role in the international floriculture market (van der Vorst et al., 2012). The Dutch auction system is unique in the world in scale and impact and is guiding for price points even in markets not touching the Dutch system (Melese & Whitfield, 2023).
This large scale floriculture market on a relatively small footprint has enabled an extensive supporting network of companies, networks and knowledge institutes. Besides the direct sales of fresh flowers and plants, this allows the actors in the Netherlands to leverage economic benefits due to both their logistic system and knowledge base with accompanying innovations. For the logistic systems, the presence of the auctions of Royal FloraHolland places the Netherlands at the centre of many international networks by providing goods to other European players. Due to the scale of the auction and its excellent

connections that are both airborne (Schiphol) and seaborne (Port of Rotterdam), the route via Royal FloraHolland is a part of most supply chains for ornamentals in north-western Europe. Royal FloraHolland is a cooperative organisation owned by growers in The Netherlands and acts as an intermediary between the growers and the traders.
The knowledge base in the floriculture is composed of both institutions and companies that provide innovation to the sector. Institutions like Wageningen University and Research or InHolland Applied Sciences provide the knowledge base for the market to operate on and help create a network of companies and startups to turn this knowledge into business opportunities. In the field of crop enrichment, Dutch companies are market leaders but their position is threatened by the European ban on direct genetic modification. Actors are also positioning themselves ahead of the expected diversification in horticulture towards emerging markets like lab-grown meat, algae production and urban agriculture.
The Dutch market is expected to maintain its relevance in the international context but with a reposition to more specialized tasks. Producers of fresh flowers are expected to be out-competed on scale by low production costs countries, necessitating a shift towards niche products that lack economies of scale. Besides this niche production target, the Dutch production of orchids is expected to remain strong as well due to its knowledge base providing services for international partners. Recently political challenges related to the use of land as well as the use of foreign labor created higher pressure on the existing sector (Blankestijn & Jongsma, 2024) (Blankestijn, 2024).

3.5. Floriculture logistics

As the focus of the thesis project is placed on the supply chain of a floriculture business, this section will provide context for the existing logistics operations in the floriculture sector. First, the traditional supply chain will be investigated along with some examples of existing supply chains. Next, the logistic control models used in these chains will be discussed.

3.5.1. Supply chain activities

The supply chain for fresh flowers in the Netherlands is illustrated in figure 3.2. This is a rich picture representation of the current situation on the market. Rich pictures are created based on a soft systems methodology approach (Checkland, 2000). The supply chain starts with the production process as was described earlier. Here, breeders decide what types of seeds and bulbs they want to be part of their portfolio. This is influenced by the response of growers and wholesalers on the trade show to their portfolio. Propagators then prepare the production step by creating starting material from the seeds and bulbs for the growers. The growers trade their produce to a differing combination between the auction and direct contracts with wholesalers. Here, imports from foreign growers also enter the supply chain. The auction process starts with the collection of produce at the growers and this is transported to the auction warehouse, often by dedicated logistic service providers. At the auction warehouse, the products are inspected and classified before they are brought to auction. After the auctioning, the goods are shipped from the temporary warehouse to a distribution partner that will provide transport for the next step in the chain. This could be a wholesaler who will transport the produce to the domestic market or prepare it for export. The auction also directly delivers to markets, especially for the larger volume purchases. In the market, three distinct categories are differentiated based on (van Horen, 2017), where the product is sold to the final consumer and the supply chain ends.
For the Dutch market, the growers' main outlet channel is Royal FloraHolland, which offers both an auction and services direct trades between growers and buyers. Through Royal FloraHolland, most imports also enter the chain. Most goods flow through at least one trader, being the importers, exporters and wholesalers. The connections in the chain are often outsourced to external logistics service providers. For big box sellers, the market can be defined as demand-driven. On the other hand, for the specialist stores, the market is supply-driven (van der Vorst et al., 2012).
A different configuration of supply chain exists in for example the German market. Here, there is no large auction system that serves as a central focus of logistics operations. (Drechsler & Holzapfel, 2023) note that in this market condition, the chain is more unified than in the Dutch market. Due to a lack of scale to gain benefits for specialisation, companies are more often operating in more than one area of the chain (production, trading, sales). It is also more common for German growers to have direct contracts with retail partners without the auction or a wholesaler functioning as an intermediary.

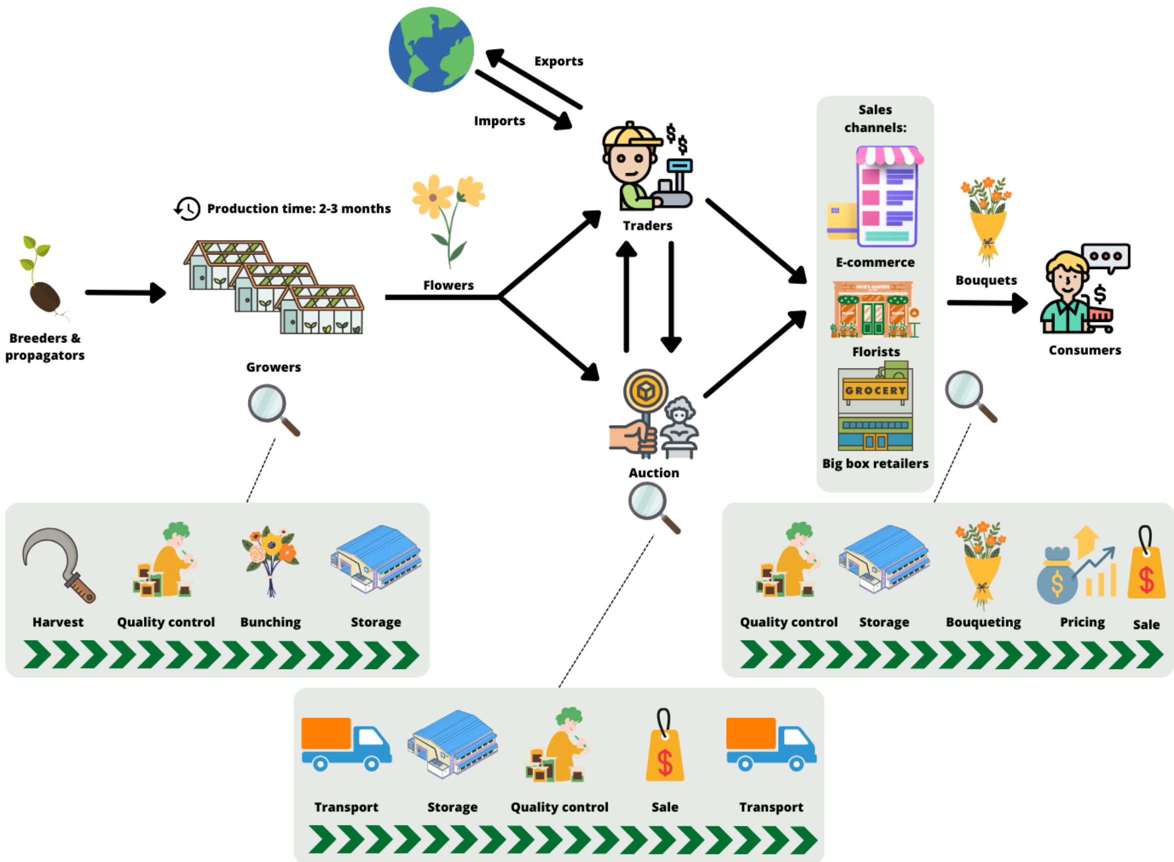

Figure 3.2: A rich picture of the activities along the supply chain in the floriculture industry in The Netherlands.

3.5.2. Logistic control models

Due to the characteristics of the fresh flower product, proper care needs to be taken in the supply chain to prevent damage and loss of value before sales. The low shelf life also stresses the importance of timing in the logistics as storage is often impractical and uneconomical. For this reason it is observed that smaller channels tend to operate their logistics with an Economic Order Quantity (EOQ) approach, where they order their needs for a specific period at fixed time intervals. Specialist stores are quoted to order at the beginning of every week, processing remaining unsold products over the weekend in low shelf life products for ceremonies like weddings and funerals. Big box retailers like supermarkets and garden centers have the scale and frequency of transport that they can afford to apply just-in-time (JIT) logistics to receive and process their goods continuously from the auction and wholesalers.
The scale of the number of growers in the Dutch market and the imports going through the auction system makes the system a push market for growers. Growers attempt to anticipate trends in consumption patterns to a limited extent and are not flexible enough to adapt quickly to changes in demand, forcing them to rely on the auction as their sales channel. This push market condition limits the bargaining power of the growers within the system and also limits the percentage of the value chain that they can capture.
(van der Vorst et al., 2012) identified five key issues for the design and management of the logistics process:

- **Robust and flexible quality-driven logistics:** The sector deals with strong dynamics and uncertainties in both supply and demand. This requires a flexible logistics set-up that is also robust enough to perform under these conditions. This is not aided by the characteristics of the product: packaging and the environmental conditions during storage and transport have a large influence on the quality of the final product. Real-time decision making in the logistics chain is therefore necessary (de Keizer et al., 2015).
- **Differentiation in the demand-driven market:** As the project proposal aims to present itself in the detail channel, customers expect a high value product with many choices available and high quality. This means that when a large focus of the project will be on the sale of a single producer, this channel will need to be able to provide this differentiation.
- **Transparency and an advanced information infrastructure:** data-driven visualisation of the trade network can help provide clarity for all actors involved in the system about the operations underway. By exchanging more information in the network, further transparency is provided that can help in matching demand and supply as well as reduce uncertainties in the system.
- **Innovative collaborative distribution strategies:** the floriculture market is struggling with the amount of rush orders and the required logistical processes to fulfill these. By collaborating on a distribution network and strategy, demand can be evened out due to scale and thus reduce the time pressure on deliveries. This approach with for example strategic reserves may help open up new transport modalities like rail and ship that were previously unviable due to time constraints.
- **Collaborative logistics:** in spite of existing collaborations in the floriculture sector, transport is still mostly managed independently from point-to-point. As the sector is moving away from a hub-spoke model towards direct links, the importance of consolidation of flows grows. Especially with a more transparent and virtual network, collaboration on transport can aid in the performance of the sector.

3.6. Automated vending points

A part of the project proposal is the usage of automated points of sale to allow for flexibility, scalability and modularity in the deployment of the vending locations. For these concepts, it is important to correctly predict consumer demand and to replenish them at the correct place and correct time. This section will discuss both requirements.

3.6.1. Demand forecasting

Retail demand forecasting consists of the complex task to predict the demand from customers in the supply chain over multiple levels and across multiple timescales. For the proposed concept, the automated points of sale must mainly be supplied in time for the production in the accompanying greenhouse production location. That puts a high pressure on the quality of the demand forecast: it must be able to communicate the expected sales of products at specific point-of-sales, in advance of their respective growing times, in order to allow the greenhouse to produce the flowers in time. This requires a good understanding of the customer market characteristics and their expected demand, as well as a model that can transform input data into usable guidelines for day-to-day operations.

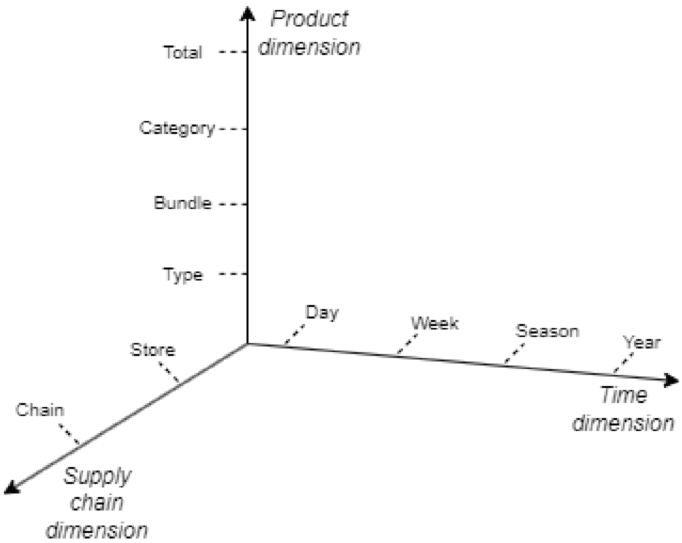

Figure 3.3: Multidimensional hierarchies in retail forecasting. Adapted from (Fildes et al., 2022).

(Fildes et al., 2022) describes the shift from brick-and-mortar stores to an omnichannel environment as a significant challenge in retail forecasting. An important factor here is whether the new automated sales channel will provide complementary sales or substitution. The paper also describes the importance of the three axes of forecasting in retail: time, product and supply chain (see figure 3.3). On the supply chain dimension, the demand along different points of the supply chain are given. The chain level for example would indicate how much of a single product type must be produced at the greenhouse, whereas the store level would be important for replenishment of vending machines. The time dimension relates to the level of time for the decision-making around demand. Flower production has seasonal influences on the production side, and on demand side certain (holi-)days like Valentine's lead to demand spikes. Finally, the product dimension details the different levels relevant for the product itself: in this case flower bulb type, packaging, potted plants etc. The review study by Fildes indicates a strong body of evidence for the performance of causal methods based on linear regressions, and a growing interest in using nonlinear and machine learning methods for demand forecasting where traditional methods underperform. These methods however still show mixed results. Benhamida et al. (Benhamida et al., 2021) describe the applicability of time-series methods for forecasting for an online retailer and they expanded upon basic forecasting by addressing new product forecasting. A framework for this forecasting method is provided in the article, with proposed future research in data pre-processing, missed sales predictions and price optimisation integration.

3.6.2. Replenishment of automated vending machines

The concept under investigation proposes to use automated points-of-sale for the vending of flowers, including vending machines and unmanned shops. These concepts have already proven to be highly popular in other branches of retail (Grzybowska et al., 2020), and recently in the Netherlands some floriculture entrepreneurs have launched their own vending machines for flowers as a novel market channel (FreshVendi, 2021). Whilst the potential might be clear, the management of these types of networks is complex. Inventory management, product placement and pricing strategies are some of the challenges encountered in the machine and each of these challenges have their own impacts on the logistical system replenishing the machines. These logistical systems are therefore often based on a Vendor Managed Inventory scheme, where a single controller determines the (re)stocking and product placements in the network of machines (Waller et al., 1999).

Such a system is greatly aided by the usage of real-time data in the decision-support methods, and the prevalence of the internet aids in providing such a dataset for the system. (Poon et al., 2010) propose an architecture based on such a method of real-time data gathering where the machines operate in a three-tier system:

1. **Tier 1:** Real-time data collection and connection. Here, each vending machine captures its status using the installed sensors in the machine and transmits the information over the internet back to a central hub. For the Qabani concept, these sensors could include not only stock levels, but also for example environmental measurements like humidity and temperature as a measure of quality of the product.
2. **Tier 2:** Data storage. In this tier, all data provided by the machines is gathered and placed in a central database.
3. **Tier 3:** Inventory control and data analysis. Finally, here the data provided by all machines is processed by a mathematical model that controls the inventory of the machines and creates an replenishment planning. In the authors' model, this system was limited to simple out-of-stock minimization, but this model can of course be expanded greatly to include multiple other factors in the decision-making like the earlier mentioned linear regression (Zheng & Li, 2018) or nonlinear (Grzybowska et al., 2020) demand forecasting models.

One of the logistical methods that operators of vending machines can use in the replenishment operations is the so-called milk-run: a concept where a dedicated vehicle follows a predefined route to deliver products to machines. Such a concept can be used in both the convergent and divergent direction in logistics: a milk-run can draw goods from multiple suppliers in one go or deliver products to multiple points-of-sale on a single route. The main benefits of this concept are a reduction in transport costs due to consolidation and the potential to outsource the routes to external parties (third-party logistics) (Brar & Saini, 2011).

3.7. Key actors, values and needs

To help in the development of the artefact that will solve the problem statement, an investigation into key actors, their values and needs has been performed. This is based on the literature review and interviews in this chapter. Selected key actors, their values and needs are listed in table 3.2. A more extensive power-influence grid with all actors in the system is found in appendix A.

Table 3.2: Key actors and their respective *values* and needs

Actor	Values and needs
Growers	Growers desire a high performance production location to create *economic growth* where they will be able to provide high *quality* products and thus have *pride in their work*. They are *entrepreneurial* but also like the *certainty* that a demand-driven market can provide. Growers need to be convinced by the success of the novel system to participate more actively.
Auction system	The auction wants to maintain the status quo where they are *powerful* and operate a central role in the system. They are driven by *economic growth* whilst being *innovative* to maintain their position. The auction functions by coordinating *cooperation* between other actors in the system.
Consumers	Consumers value the *therapeutic effect of flowers*, and desire a high *quality* for an *affordable* price. They want their flowers to be produced in a *sustainable* way which is also *traceable* and *local*. They cooperate with florists to purchase goods and investigate the production process at growers.
Breeders	Breeders value their capability to *innovate* and provide *excellence* for growers and consumers. They need to have a market for their products to be able to create new varieties and desire cooperation from growers to trial their new products.
Logistics service providers	Logistics service providers want to provide *efficiency* and *excellence* in the transport of fresh flowers for partners in the chain. They desire to be compensated adequately for their work. They cooperate with growers and florists to distribute goods.
Florists	Florists desire to provide *quality* to consumers by selling them fresh flowers to fulfill their needs. They are *entrepreneurial* and have a large *pride in their work*. In return, they desire to be compensated adequately for their work. They cooperate with logistics service providers to receive goods.
Governmental actors (Dutch government, local municipalities)	Governmental actors want to promote *economic growth* within their jurisdiction to provide *welfare* for their citizens. Besides these motives, they want to promote *sustainable* practices for both consumer citizens and businesses.
Knowledge institutes & companies	Knowledge providers want to demonstrate their capability to *innovate* in the processes of floriculture production and provide *excellence* for growers.

3.8. Conclusions and contribution of chapter

In this chapter, the following conclusions were drawn:

- The floriculture market exists of the sale of flowers and plants, which can be categorised as ornamentals and fresh cut flowers. The last category is often sold bunched with other (types) of flowers as a bouquet. The focus of this design will be on the category of fresh cut flowers.
- Production of fresh cut flowers is dependent on seasonality and has a growth time of around 2 months.
- The floriculture market in Europe is matured and dynamic. It has a strong local production base, with a central role for The Netherlands. Here, large scale production, innovation, sale and transport of flowers is present.
- The supply chain for fresh flowers in The Netherlands was visualised. In this current chain, an important central role is taken by market makers. The traders and the auction system possess high amounts of market power in this chain and control the flow of information.
- The logistics of fresh flowers is influenced by the product characteristics. It is a fragile product with a limited shelf life, causing the value to diminish quickly.
- When working with automated vending points, the demand at these points must be accurately forecast using a time-series method based on demand data.
- Automated vending machines need to be periodically replenished. To perform this action, milk-run logistics can be used where products can be delivered to multiple points-of-sale on a single route.
- Several actors were identified that could cooperate in the realization of a business concept based on a unified supply chain. Growers and consumers could reach each other based on their valuation of local production and quality, with breeders and knowledge institutes helping to innovate in the system.

3.8.1. Contribution to the design project

The context that has been created for the design will be useful in the following chapters as a background in which the result of the design will operate. As such, it will provide knowledge about the conditions under which the design will operate, as well as provide some design options and choices that have to be made. The representation that has been made of the supply chain will allow the creation of a concept for the design in the following chapter.

4

Establishing the problem and converting it into a concept and requirements

Based on the context sketched in the previous chapter, a problem statement and a list of requirements and constraints for the design for the unified supply chain floriculture business concept can be created. This chapter will focus on creating such a description of objectives and requirements. Using the analysis in the previous chapter, a problem statement will be postulated describing the situation that the design will attempt to solve. Next, a rich picture will be created to describe both the current situation and the situation that the designed system is supposed to fulfill. This situation will be further expanded upon by deriving functional and non-functional requirements and constraints to list the targets for the designed system.

4.1. Problem statement

As was discussed in chapter 3, the Dutch floriculture industry is currently a highly developed market which faces threats from different perspectives to position themselves for the future. A potential solutions described here to some of these issues is to unify the supply chain and start working in a demand-driven market system. Changing the entire market with a single project is not realistic, but a first proposal can be made that operates on these new principles, within the existing floriculture market. If successful, it can be applied by other actors or exported to other countries for adoption. An attempt in the form of a trial company can be the framework for a new business model that helps alleviate problems in the system. The creation of such a company would be based on a business model guided by both the unified supply chain as well as the data-driven approach to consumer demand. This unified chain would link producers and customers under one roof. To be successful on the difficult market, it must provide added value compared to the oversaturated flower market that already exists in the Netherlands.
The problem statement can thus be defined as follows:

> *To launch a business model facing the challenges of the Dutch floriculture market, actors in the system need to create a unified supply chain from production to sales. Such a system needs to be economically beneficial to both partners in the value chain as well as consumers. The system would need to include a production location for fresh flowers, a network of points-of-sale as well as a managed supply chain and accompanying data management system. When successful, this system would be an example for later adoption by other stakeholders in the system to transform their practices towards a future-proof model.*

The performance of such a business model would be based around the performance of its supply chain. The design and execution of this supply chain is thus highly relevant for success of the proposal. The

main design challenge identified is that no design has been made on the functioning of a system of vendors working closely together with a producer. This design would be necessary to start operating the supply chain within this system. Existing floriculture supply chain solutions are not suited for the proposed system as they still focus on the supply-driven linear market and lack the integration of data-driven demand forecasting. Other markets that do operate based on data-driven demand forecasting are also different to the proposed system due to the difficulties related to the production, handling and transport of fresh flowers compared to more easy to handle goods. Finally, by integrating the production partner into the system, a unified supply chain is proposed that is novel and relevant to research. The design of such a supply chain will therefore be the focus of this thesis work.
Besides applications in the floriculture industry, the resulting design that solves the challenge can be expanded to other sectors such as fresh plants, produce or the wider food & catering market. As these markets deal with similar challenges related to product handling, the resulting supply chain design can also be applied here as the start of a creation of a new business concept combining the production and sales of their respective goods.

4.2. Rich pictures

One of the methods advised in soft systems methodology by (Checkland, 2000) is the rich picture. In this way, a depiction with pictograms of a situation can aid in the holistic view of a complex situation. For the existing supply chain system for fresh flowers in the Netherlands, figure 3.2 depicts such a rich picture.
In this rich picture, the flower journey through the traditional supply chain is visualised. After ordering from the breeders & propagators, growers produce fresh flowers with a production time of two to three months. At the end of the growth period, the fresh flowers are harvested from the plants and internal quality control is performed. Next, these flowers are bunched in groups of ten similar quality flowers and stored internally.
From this point on, the flowers enter the floriculture market and are distributed along the chain towards new actors and ultimately to the consumers. Growers sell their flowers to either traders or directly on the auction system. Traders also interact with the international flower market by means of imports and exports. The market allows for varied interactions between traders and the auction, with flowers able to change ownership multiple times.
For the flowers themselves, in this market system they are first of all transported from the growers to the central hub locations of the traders or auction. Here, they are temporarily stored. A new round of quality control takes place such that a guarantee and label of quality can be given to later purchasers. Using this quality label and the current market conditions, a price is determined during the sales process for the flowers. When sold, the flowers are retrieved from storage and transported to the buyer. The three earlier mentioned sales channels (e-commerce, specialty shops like florists, and big box retailers) source their flowers from a variation of traders and directly from the auction. They process the flowers into bouquets and these are then finally sold to the consumers.
Within figure 4.1, an area of operation for a centrally coordinated supply chain is indicated. This area would be influenced by the business model discussed in earlier chapters of a direct link from the growers to the consumers. In this situation, flowers would be retrieved from grower(s) and potential external sources, and bouquets would be sold to consumers. The internal organization of the supply chain would no longer be fragmented but centrally coordinated by a single entity, allowing for the benefits of such a chain to materialise.
Figure 4.2 depicts a rich picture of the proposed business model. Here, the chain still starts with sourcing from breeders and propagators and the production of fresh flowers by the growers. Directly after harvest, the coordinated supply chain commences. After internal quality control, the flowers do not need to be bunched in groups of similar types but can directly be matched with other types of flowers into bouquets for purchase by consumers. These bouquets can then be stored internally under proper climate conditions before being transported to the sales locations. Pricing of the bouquets is then controlled by the central coordination entity such that the optimal sales performance can be achieved. The consumer thus receives a bouquet directly sourced from the grower without multiple steps in the floriculture market.
A focus point in this rich picture is the central coordination entity. This institutional artifact should plan for the correct operations in the previously described flower journey. First of all, it should contain a

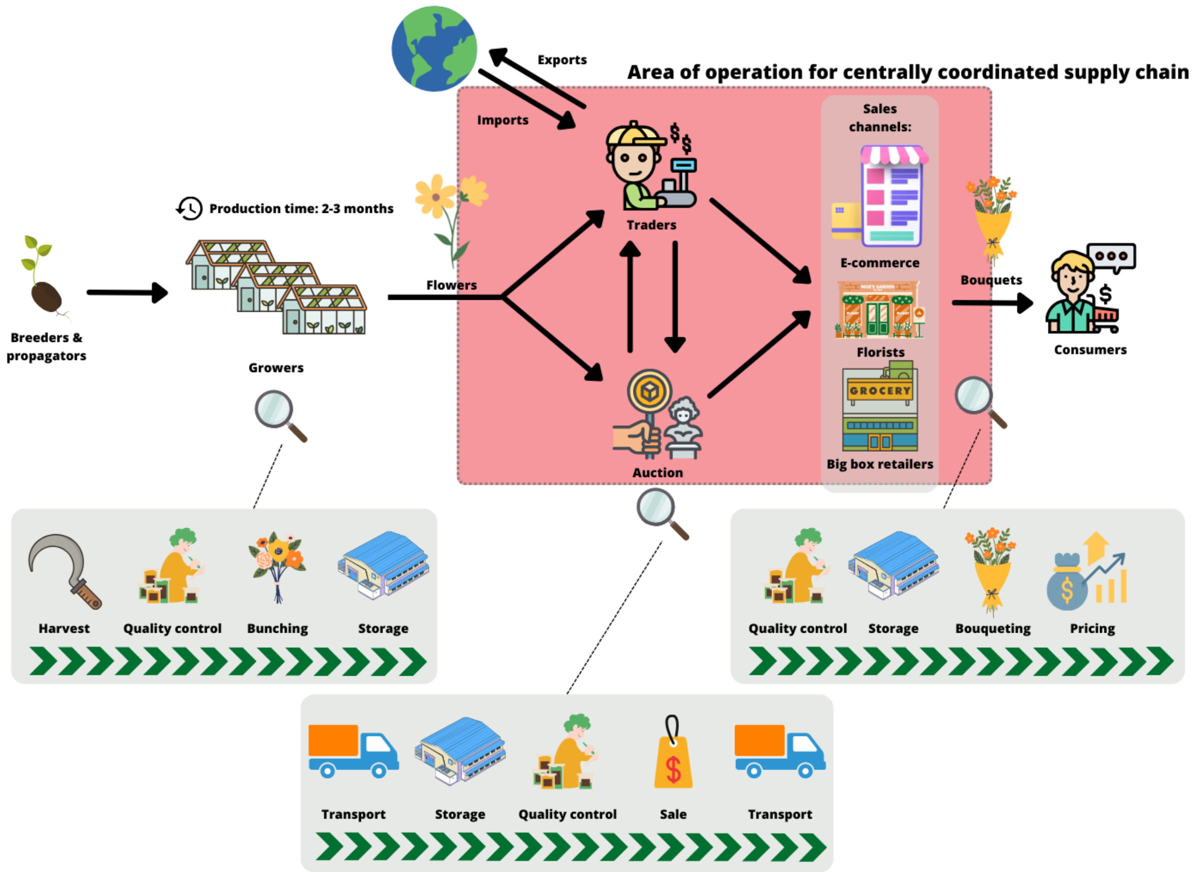

Figure 4.1: A rich picture detailing the flower journey in the current situation on the Dutch market.

system to forecast the consumer demand. In this way, it can use the customer preferences information to directly advise the growers on what types of flowers they should produce. Then, an optimal harvest can be prepared such that minimal storage is necessary before final sale to consumer. This improves the quality and thus value of the product.
By forecasting consumer demand correctly, bouquets can be prepared that will be a match between both the consumers' desires and values as well as the current harvest. In this way, the highest percentage of flowers can be created by partnered growers with minimal need for external sourcing. The coordination system should thus contain knowledge about bouqueting techniques and trends as well as the capability to transform the flowers into the selected bouquets. These bouquets must then be able to be stored before they are due for transport.
To plan for transport, the coordination entity should have knowledge about the forecast per point of sale for consumers, as well as monitor the actual performance of the sales locations. In this way, a plan can be made such that the expected consumer demand between deliveries can be fulfilled by the stock at the point of sale. The required bouquets can then be retrieved from storage and transported to their respective sales location.
A final role of the central coordination artifact is pricing. By combining data from both the production side of the chain and consumer preferences, an optimal price point can be selected for each bouquet independently. Such a system could then also adapt prices of the bouquets depending on actual performance and coordinate clearance or sales due to for example quality decay. By controlling this pricing power centrally between grower and consumer, a better value for both the consumer as well as the business model should be possible.

4.3. Requirements and constraints

The flower journey in the rich picture of the proposed situation can be translated into constraints and requirements for the design of the supply chain. A constraint denotes a concept that the supply chain

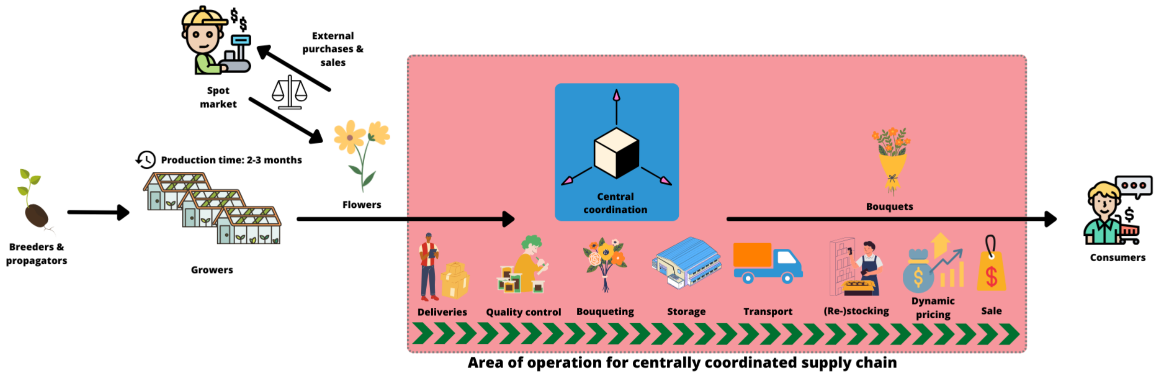

Figure 4.2: A rich picture detailing the flower journey in the proposed situation.

should fulfil and thus limits the design space. For the review of the design alternatives in chapter 7, these constraints can either be fulfilled or failed, with no score in between. The requirements however indicate goals for the designed system that could also be partially met.

4.3.1. Constraints

The following constraints were defined for the design of the supply chain of the floriculture business concept:

- **C1:** The system must be feasible to implement within three years.
- **C2:** The product must be shelf-stable for at least 7 days when delivered at a point of sale.
- **C3:** The designed system for the supply chain must operate within the wider business concept including a production location and points of sale.
- **C4:** The system must be able to communicate demand internally three months ahead of time.
- **C5:** The feasibility of the system must be validated by expert review.

Table 4.1 further explains the underpinning of the constraints.

Table 4.1: The design constraints and the underpinning of their selection.

Constraint	Underpinning
C1	As the development of the production location is expected to take approximately three years, the supply chain should be able to be operable within a similar timeframe. Derived from an interview with client T. Kester.
C2	In order to capture the unique selling point of high quality fresh flowers straight from the growers, the supply chain should operate swiftly enough that a long shelf-stable time can be guaranteed to customers. Derived from an interview with client T. Kester.
C3	The supply chain design is part of a larger business concept including the self-operated production location and the automated vending locations distributed around the country. It should function within this context. Derived from an interview with client T. Kester.
C4	An important factor in the design of the supply chain is that the forecasts made internally for demand need to be communicated to the production location ahead of the growing times for the fresh flowers. This implies a lead time of three months for most products. Derived from an interview with expert R. Ossevoort.
C5	To verify the feasibility of the system, it should be evaluated and validated in a workshop by experts.

4.3.2. Requirements

Next, the requirements of the system can be determined. These will be split into functional (FR) and non-functional (NR) requirements. A functional requirement indicates a goal that the designed system should meet, whereas a non-functional requirement indicates something the system should have. The requirements are also based on the steps in the flower journey in the proposed model in figure 4.2. This led to the following sets of functional requirements:

- **FR1:** The system should receive freshly harvested flowers.
- **FR2:** The system should order and sell over- and underproduction on an external market.
- **FR3:** The system should be able to trace every product throughout the supply chain.
- **FR4:** The system should check for quality of the harvested and received flowers.
- **FR5:** The system should predict and monitor consumer preferences in bouquets and flower types.
- **FR6:** The system should provide guidance on what bouquets to create.
- **FR7:** The system should be able to create bouquets from freshly harvested flowers based on the earlier mentioned guidance.
- **FR8:** The system should be able to adequately store both bouquets and freshly harvested flowers for two days.
- **FR9:** The system should predict what demand will be per vending location per day.
- **FR10:** The system should monitor vending location performance.
- **FR11:** The system should combine demand prediction and performance per location into a transport planning.
- **FR12:** The system should offer delivery of bouquets to multiple points of sale based on the transport planning.
- **FR13:** The system should determine pricing on an individual product basis using the data about the supply chain.
- **FR14:** The system should refill, clean and maintain the vending locations.

Table 4.2 further explains the underpinning of the functional requirements.

The following non-functional requirements were synthesised for the design phase:

- **NR1:** The system should have minimal initial investment.
- **NR2:** The system should be scalable with a lead time of two months.
- **NR3:** The system should have flexibility to adapt to high daily, weekly and seasonal fluctuations in capacity.
- **NR4:** The system should have a central coordination mechanism of the supply chain.
- **NR5:** The system should have a data-driven approach towards the business model.
- **NR6:** The system should have capacity to manage, process and act based on the data in the supply chain.
- **NR7:** The system should have standards for quality control.
- **NR8:** The system should have space and methods to create bouquets.
- **NR9:** The system should have adequate storage facilities for fresh flowers.
- **NR10:** The system should have frequent and flexible availability of transport to points of sale.
- **NR11:** The system should have a clear pricing strategy.
- **NR12:** The system should have five different options available for customers at the point-of-sale.

Table 4.3 further explains the underpinning of the non-functional requirements.

4.4. Conclusions and contribution of chapter

In this chapter, the problem statement was refined based on the context of the design investigated in the previous chapter. The following problem statement was derived:

> *To launch a business model facing the challenges of the Dutch floriculture market, actors in the system need to create a unified supply chain from production to sales. Such a system needs to be economically beneficial to both partners in the value chain as well as consumers. The system would need to include a production location for fresh flowers, a network of points-of-sale as well as a managed supply chain and accompanying data management system. When successful, this system would be an example for later adoption by other stakeholders in the system to transform their practices towards a future-proof model.*

Based on the rich picture approach, the area of operation for a centrally coordinated supply chain in the current situation on the Dutch market was converted into a unified supply chain concept. Here, eight functions are envisioned that need to be performed in the supply chain. These are deliveries, quality control, bouqueting, storage, transport, (re-)stocking, dynamic pricing and sale. These steps are governed by a central coordination system.
For this concept, the design space is limited by a set of constraints and requirements created in this chapter. These consist of constraints, functional and non-functional requirements.

4.4.1. Contribution to the design project

The problem statement derived in this chapter further helps clarify what the design objective aims to solve. This was created based on the context discussed in chapter 3. The concept that was generated for the flower journey of the unified supply chain has formed the basis for the list of constraints and requirements that were generated for the design. This list has provided a design space to operate in and will provide the basis for the functional design in the next chapter.

Table 4.2: The designed system functional requirements and the reasoning behind their selection.

Requirement	Underpinning
FR1	On the front end of the supply chain, the freshly harvested flowers should be received from the grower(s) with sufficient care to maintain the quality as well as provide traceability within the coordination entity for the flowers such that they can be processed later on.
FR2	Interviews with experts R. Ossevoort and J. Westra indicated that a range of products that are sold on the Dutch floriculture market cannot be produced in the Netherlands or are economically unattractive to produce in small quantities. External sourcing of these product types will thus be required, as well as for materiel like bouquet paper, plant food and vases. Similarly, overproduction may lead to a situation where not all fresh flowers can be sold within the internal sales channels and therefore an outlet for external sales is required to prevent spoilage of the overproduction.
FR3	The supply chain should have traceability from both freshly harvested flowers as well as externally sourced products. In this way, the pricing strategy of the business model can operate fully data driven by determining value of products on an individual basis using this traced data throughout the chain.
FR4	Before bouquets are created, the flowers should be checked for quality to guarantee the customer receives the product quality that the brand is planning to offer.
FR5	As the coordination system should be able to predict consumer demand per point of sale, consumption patterns and preferences should be continuously monitored in the dynamic floriculture market to remain flexible and to adapt to the new situation (Drechsler & Holzapfel, 2023). These preferences can then later be used in the coordination artifact to select the product line (the bouquets) that the consumer can purchase. It is also a guideline for the grower(s) for what they should produce.
FR6	Based on the consumption preferences, bouquets can be designed from the flowers that are expected to be harvested in the upcoming period. T. Kester indicated in the interview that bouquets of different flower varieties provide both the largest market share and the highest profit margins for florists.
FR6	Within the supply chain, the freshly harvested flower varieties must be brought together such that bouquets can be created from the separate stems. This should be done based on the designs for these bouquets created by the central coordination artifact.
FR8	Bouquets that have been prepared and freshly harvested flowers that cannot be immediately transformed into bouquets must be stored under proper environmental conditions. This prevents quality decay and thus improves the value of the final product (van der Vorst et al., 2012). R. Ossevoort indicated that the industry average processing time of two days should be met to guarantee the desired quality level for consumers.
FR9	The coordination system should provide a forecast of demand per location based on the characteristics of the vending location to be able to plan the delivery of new product for restocking. To allow for frequent restocking, this forecast should be updated at least daily in time for new delivery trips.
FR10	The coordination system should be able to learn from and adapt to performance of different vending locations separately and adjust its planning accordingly.
FR11	Based on the data gathered in the coordination artifact, a prediction should be made about the expected demand per point of sale over the time between resupplies. This can then be translated into a selection of produced bouquets from storage and delivery methods to create a transport planning.
FR12	There should be a delivery system in operation that is able to make frequent trips between the hub(s) and the points of sale to be able to restock and maintain the vending locations based on the transport planning earlier mentioned.
FR13	With the data gathered in the coordination artifact, the products should be able to be traced on an individual level throughout the supply chain. Therefore an individual pricing should be possible based on the entire data set about for example desirability, freshness, production costs and age. Such a system could optimize value for both the consumer as well as the business model.
FR14	At each visit to a vending location, the transported goods should be restocked into the point of sale. Any necessary cleaning and maintenance tasks should also be performed to guarantee the proper appearance of the locations.

Table 4.3: The non-functional design requirements and the underpinning of their selection.

Requirement	Underpinning
NR1	As the business concept is in a start-up phase, it is desirable to have low initial investment due to limited available cash for the supply chain. This was taken from the interview with T. Kester.
NR2	The deployment of the automated vending machines is expected to ramp up after initial trials have been successful. The supply chain should therefore be able to adapt to a scale-up within two months, which is the expected delivery time of a vending machine. Expert interviews with R. Ossevoort and ACN Vending supplied this information.
NR3	As fresh flowers show high fluctuations in consumer demand both due to weekly effects as well as seasonal influences, the supply chain should be flexible and able to adapt to these changing circumstances in demand and supply (Drechsler & Holzapfel, 2023).
NR4	As was discussed in the rich picture of the proposed business model, a central coordination artifact is required to steer all operations in the supply chain and create the value for both the consumer and the business. This artifact should be institutional as well as physical: it should come with its own rule-sets and methods as well as with personnel and IT-systems to fulfill its tasks.
NR5	To be able to create the central coordination system, data-driven digital platforms are required to be able to process and leverage the large amounts of data that will both be created as well as needed to perform its task. The business model should thus from the start be based on a data-driven approach. (De Reuver et al., 2018) mentions the many examples of companies that have benefited from shaping their business around a digital platform. The central coordination platform for this design can be implemented as a digital platform which can be expected to prove beneficial to the company as well.
NR6	The creation of a digital platform requires the creation or adoption of an IT-system that will help in managing and processing the data created and required in the chain. (Fildes et al., 2022) mention the importance of IT systems for forecasting demand and R. Ossevoort in his interview indicated the lack of IT-based systems in the floriculture industry as a factor limiting performance.
NR7	Whilst quality of the products in the chain is of importance, a separate definition of quality can be created for the direct sales to consumers. Interviews with experts indicated that especially the quality control guidelines guaranteeing uniformity across suppliers are less relevant for flowers that will directly be transformed into a bouquet. This own set of rules should be sufficient to guarantee quality for the consumer but not be unnecessarily restrictive.
NR8	A production location that is capable of transforming the freshly harvested flowers into bouquets is required to be able to create the final product for the consumer within the business model itself.
NR9	To facilitate manoeuvring space and time in the supply chain, at the hub location(s) there should be adequate storage including climate controlled and cooled environments for the temporary stocking of fresh flowers from internal and external sources. This prevents quality and value decay (van der Vorst et al., 2012).
NR10	As consumer demand is difficult to predict perfectly, daily adaptations to the delivery schedule will be made based on actual performance in sales. This requires flexibility in daily operations of the delivery system, increasing or decreasing the number of stops
NR11	In cooperation with other departments of the company, a strategy must be developed which provides the coordination artifact with a rule-set for pricing. Here, various factors influencing pricing like quality, demand and production costs should be translated into a pricing methodology that optimizes value for the business whilst providing a competitive offer for the consumer.
NR12	To offer sufficient choices for different consumer preferences as well as a target for the system replenishment, it was decided that at least five different options must be available at all times at the points of sale. This decision is based on experience in the florist market gathered from Priva in the interview with J. Westra.

5

Design of physical supply chain operations

This chapter describes the first part of the design process that fulfils the requirements set in chapter 4. The design process is split in two parts: physical operations and digital systems. In this design exercise, the leading design is that of the physical supply chain. The choices made in this part of the design provide guidance to those in the digital systems design. This chapter will cover the creation of four different design approaches for the physical supply chain design. The design of the digital systems will be covered in chapter 6.
The first section describes the creation of a functional design based on the rich picture concept created in chapter 4. The steps in the supply chain described there are expanded here in more detail. Following this, in section 5.2 a morphological chart is created which uses the functional design to explore different directions in the design space. The chart groups functions from the functional design created in section 5.1 and provides design options to complete the function. This morphological chart is then reviewed in section 5.3 by giving the options a rating using a method adapted from SCOR performance cards. These scores are used to provide a first review of the morphological chart. Based on this reviewed chart, in section 5.4 different design approaches are theorised that combine different well-performing options in the morphological chart into a feasible whole design. These designs and a more detailed supply chain mapping of these approaches is also given in this section.

5.1. Functional design

Based on the rich picture concept sketched in chapter 4, a general functional flow block diagram (FFBD) has been created in figure 5.1. It is focused on the physical activities in the supply chain based on the flower journey. Each function in the overall FFBD is further subdivided in subfunctions in the following sections.

The required operations are described as functions 1 to 8. While these functions are generally performed in this order, it should be noted that non-consecutive interactions may also occur within the functions. Such occurrences are further elaborated in the discussion of their expanded functional design. There will also be interactions between the digital systems and the physical supply chain processes. As the digital system has not been designed yet, it will be referred to in this chapter as the ”central coordination system”. The 8 steps of the general functional design are expanded upon in the following subsections.

Step 1: Deliveries

Figure 5.2 gives the FFBD for step 1: deliveries. Here, the product journey and steps involved for the delivery function are described. It starts with the scheduling activity of deliveries **(1.1)** such that the correct products are received at the correct time and place. These deliveries must then be received from both internal **(1.2)** and external **(1.3)** sources. Different functions have to be designed for this to

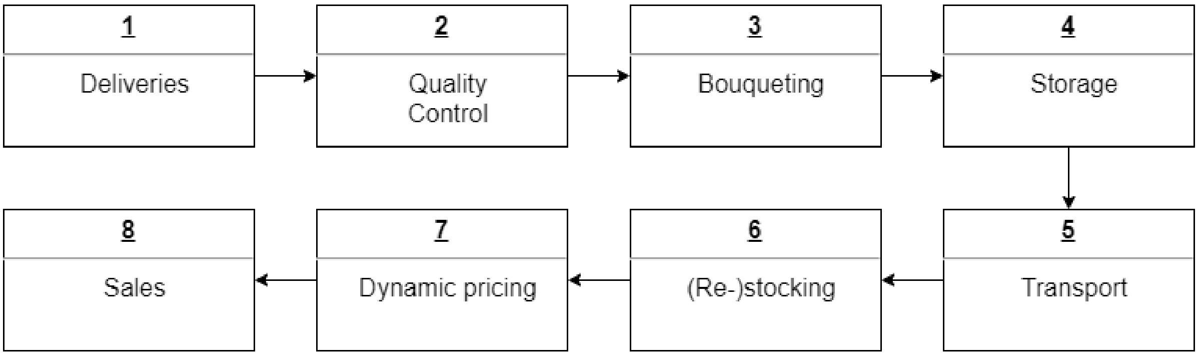

Figure 5.1: Functional flow block diagram depicting the general functional design.

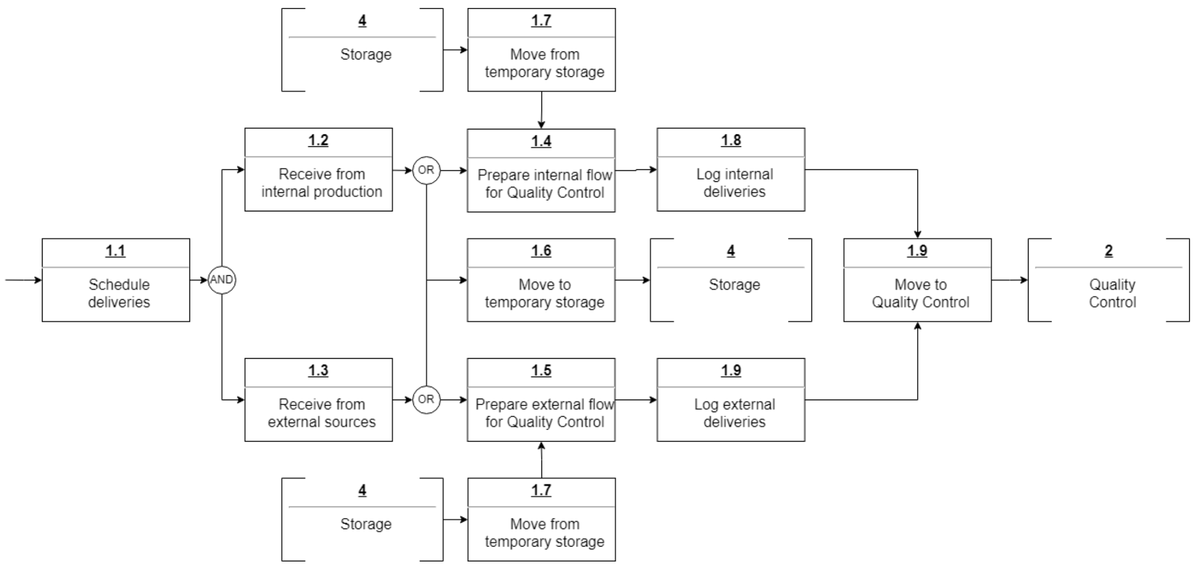

Figure 5.2: Functional flow block diagram depicting the design of step 1: deliveries.

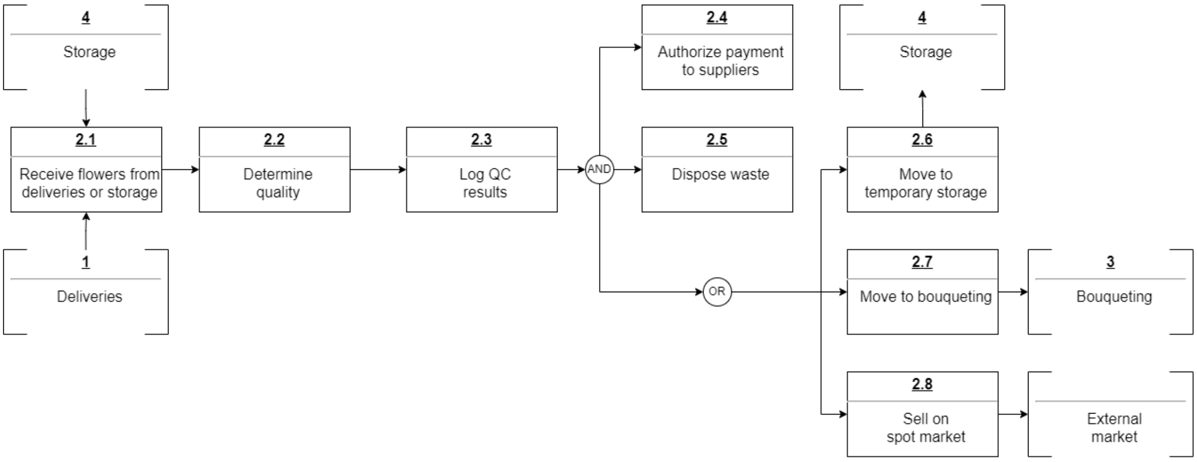

Figure 5.3: Functional flow block diagram depicting the design of step 2: Quality Control.

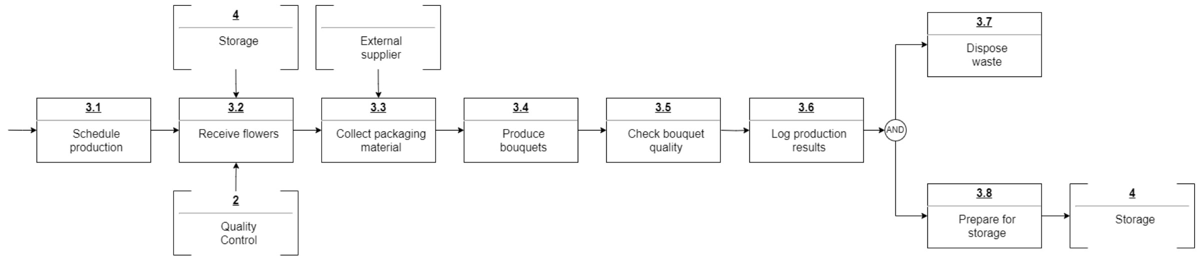

Figure 5.4: Functional flow block diagram depicting the design of step 3: bouqueting.

accommodate for potential differences in methodology required to process both flows: for example the handling devices and reception area might differ. After reception, goods can either move to temporary storage **(1.6)** before further processing or can be prepared for quality control **(1.4 & 1.5)**. Goods that have been stored temporarily can also be retrieved to rejoin the operations here **(1.7)**. Preparation during deliveries can include steps like labeling, (re-)packaging and staging operations. After this, the deliveries must be logged (**1.8 & 1.9)** both for administrative reasons and to help the planning system. Then, the goods can be moved to quality control **(1.10)**. This move can either be physical or administrative. They can also be moved to storage again.

Step 2: Quality Control

The second function is the quality control of the products. First of all, the products to be inspected are received either directly from deliveries or from temporary storage **(2.1)**. Quality inspection and verification is performed in this function according to an earlier determined set of requirements **(2.2)**. The results of this inspection is then logged in the system **(2.3)**, to update the coordination system of the entire supply chain. After QC, payment can be authorized to suppliers based on the accepted number of products **(2.4)**. Rejected products have to be disposed appropriately as waste **(2.5)**. The remaining flowers will then be moved towards one of three options. The first possibility is to temporarily store the flowers for later processing if they are not immediately required in the bouqueting lines **(2.6)**. If they are needed however, the flowers are directly moved there **(2.7)**. Finally, if the coordination system does not foresee a use for the flowers within the product lifetime, it may decide to sell off overstock on the spot market **(2.8)**.

Step 3: Bouqueting

The third function (figure 5.4) entails the production of bouquets from the flowers such that these can be sold to consumers. For this production step, a schedule must be made of for example what type and how many bouquets will be made **(3.1)**. This will be based partially on the input of the central coordination system. To start production, flowers are received in the production area either from storage or from

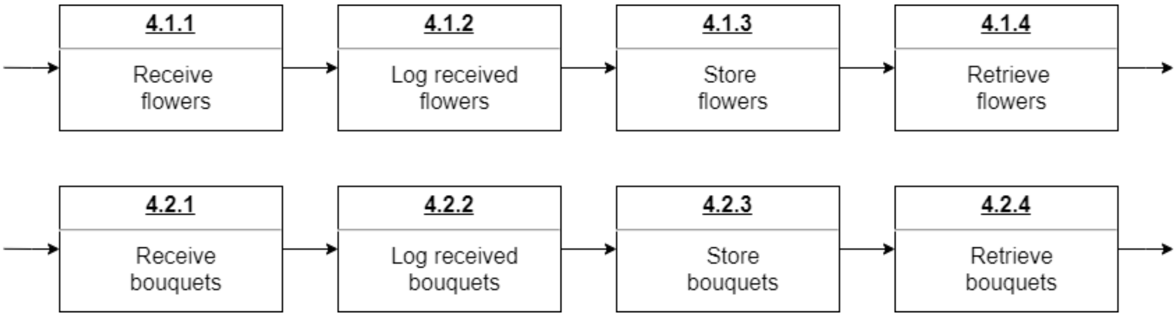

Figure 5.5: Functional flow block diagram depicting the design of step 4: storage.

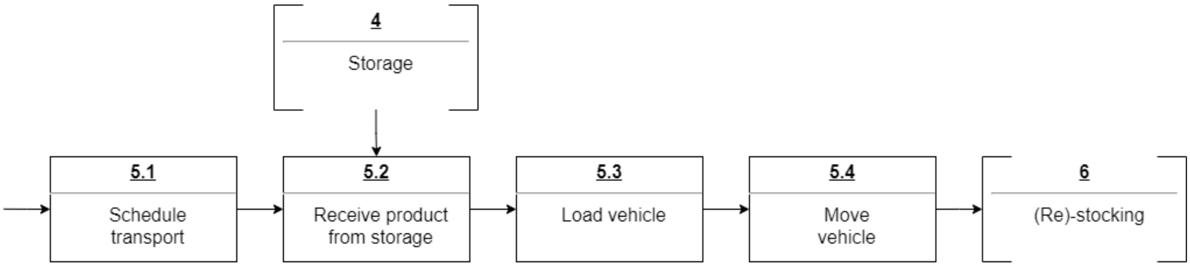

Figure 5.6: Functional flow block diagram depicting the design of step 5: transport.

QC **(3.2)**. Next, non-flower materials are collected which are required to make a bouquet **(3.3)**, which are sourced from external suppliers. These materials can be goods like plant food, wrapping paper and binding material. Using all the products, bouquets are assembled based on the production schedule **(3.4)**. These bouquets are again checked for quality **(3.5)** and the result of production is logged in the central coordination system **(3.6)**. Any waste like cuttings created by production is disposed of **(3.7)** and the resulting bouquets are moved to temporary storage before they are transported **(3.8)**.

Step 4: Storage
Function 4 (figure 5.5) describes the storage operations. Here, two parallel tracks can be seen: one for the processing of flowers and one for the processing of finished bouquets. This separation was made to accommodate the different environmental, handling and packaging requirements for both types of goods. In storage, the goods are first of all received from other operations **(4.1.1 & 4.2.1)**. Next, their placement in storage is logged in the system **(4.1.2 & 4.2.2)** and the goods are placed in their designated storage area **(4.1.3 & 4.2.3)**. As a final step, the stored goods are retrieved again, when necessary, to process further in the artefact **(4.1.4 & 4.2.4)**.

Step 5: Transport
The fifth step (figure 5.6) includes the transport of the finished bouquets from the storage location(s) to the points-of-sale. Here, the goods that have been produced according to the production planning will be divided between the different locations where consumers can purchase these goods and the distribution to these locations is centered. This process is started with the scheduling of the transport in cooperation with the central coordination system **(5.1)**. Based on this schedule, bouquets are received from the storage location **(5.2)** and are placed in a vehicle for transport to their destination **(5.3)**. This vehicle then moves to its destination **(5.4)**, where (re-)stocking can start.

Step 6: (Re-)stocking
Figure 5.7 is the FFBD of function 6: (re)-stocking. Here, the points-of-sale that consumers can use will be stocked fully or restocked partially with the bouquets transported to them from within the system. This process is scheduled **(6.1)** in close cooperation with the transport and production planning in the central coordination system. During (re-)stocking, the transporting vehicle must be received **(6.2)**

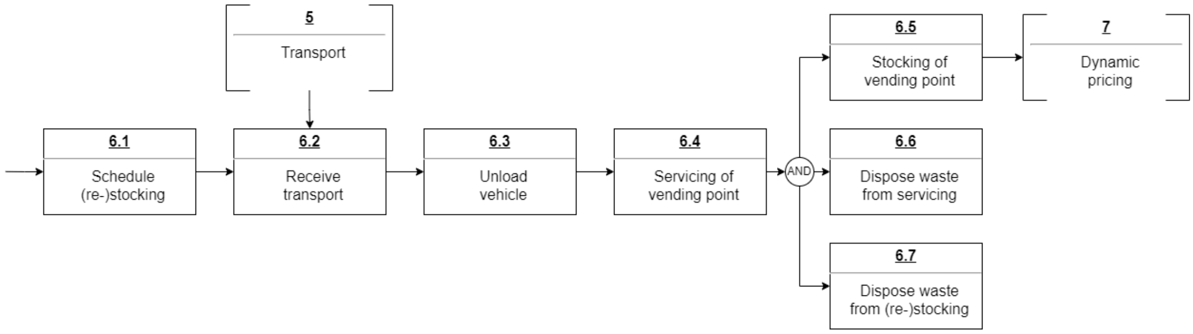

Figure 5.7: Functional flow block diagram depicting the design of step 6: (re-)stocking.

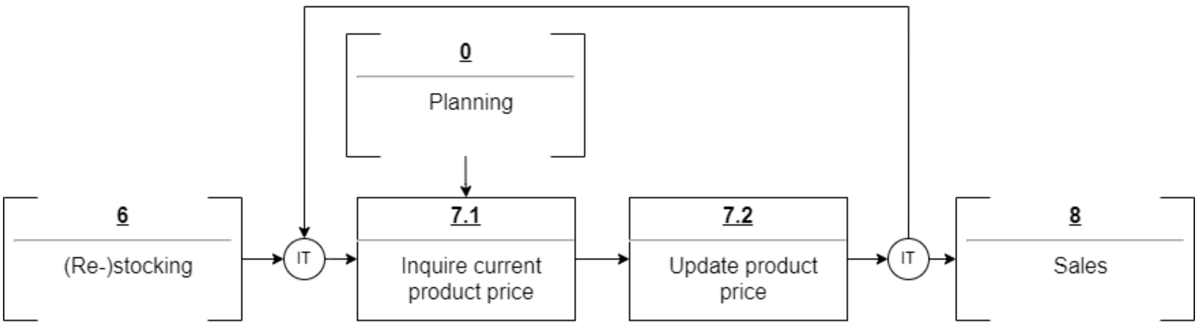

Figure 5.8: Functional flow block diagram depicting the design of step 7: dynamic pricing.

before it can be unloaded **(6.3)**. Not necessarily all goods from the vehicle have to be unloaded here. Before any stocking takes place, the vending point receives some degree of servicing **(6.4)**. This could range from simple opening of the machine up to cleaning and maintenance or disposal of old bouquets. After servicing, the machine can be stocked with the delivered bouquets **(6.5)**, any waste from servicing has to be disposed **(6.6)** and similarly, waste from (re-)stocking has to be disposed **(6.7)**. Both types of waste have to be disposed in separate functions due to the difference in consistency. This separation also allows for freedom of design about disposal on-site or externally. After (re-)stocking, the price of the product can be determined.

Step 7: Dynamic Pricing

The FFBD in figure 5.8 depicts the iterative step of the dynamic pricing process. Here, the central coordination system provides a current price for each product to the point-of-sale **(7.1)** and the system then updates the product price **(7.2)**. The frequency of the iteration is also a design parameter.

Step 8: Sales

Finally, after the price is set, the product becomes available for purchase by consumers in function 8: sales (figure 5.9). This process starts with the vending location selling to a consumer **(8.1)**, who is provided with proof of delivery **(8.2)**. To wrap up, the system logs the sale in the central coordination system **(8.3)** which can then use this information in the future planning of the system.

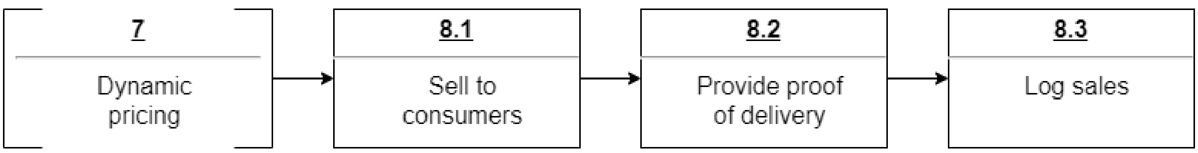

Figure 5.9: Functional flow block diagram depicting the design of step 8: sales.

5.2. Morphological chart

Based on the functional designs created in the previous section, different directions in the design space can be explored. Table 5.1 contains the morphological chart showing the different functions and options that can be used to perform the tasks. This morphological chart is only for the physical operations in the supply chain, thus functions in the functional design that depend strongly on the central planning will not be included. This includes functions like scheduling of production or the dynamic pricing concept. Functions that have a similar design space are grouped together in this morphological chart to remove redundancies. It should be noted that this does not limit these different functions to the same solution once a design is created from the morphological chart.
For each function (group), several design options are stated in the morphological chart. These options include widely used approaches within the broader supply chain sector complemented with options based on the literature study described in chapter 3. Besides this, part of the earlier performed interviews with clients and expert were dedicated to include additional options that are of interest to the floriculture supply chain specifically.
An explanation for the grouping is given below:

- **Receival:** in this process, the interaction with external suppliers is captured. All three functions describe the receival of goods from outside of the system and such their design space is similar.
- **Prepare:** in the prepare step, the packaging or handling device (HD) of a product is changed to make future processing possible. As the design space for packaging and HDs for flowers and bouquets is limited and similar, the functions are grouped in the morphological chart.
- **Move:** during the supply chain, goods have to be moved multiple times. As the handling and moving of goods is a relatively common process in supply chains, the design space applies to several functions in the design where the focus is on moving goods within a facility. However, for moving a vehicle (transporting), a separate item in the morphological chart was added.
- **Log:** the process of logging a step during the supply chain should be able to interact with the other functions that log steps in the supply chain. Due to this interoperability requirement, it is best to keep all log functions in mind as a group.
- **Quality control:** whilst the products that are checked are different in both functions (flowers and bouquets respectively), the process on a high-level design scale is similar.
- **Dispose waste (production):** the main type of waste from the production process are disposed flowers or parts thereof. As such, the functions can be grouped together.
- **(Un-)load vehicle:** it can be expected that choices made for the process of loading the vehicle will have a large influence on the methodology of unloading the vehicle, so the options here are similar.
- **Dispose waste (vending points):** the main challenge in the design space for disposing waste from the vending points is what to do with it, which is the case for the waste from both servicing and restocking. As such, these functions are grouped in the morphological chart.

5.3. Ranking of options in the morphological chart

The morphological chart in table 5.1 shows several options per function (group) that can be selected, indicating a rich design space. To proceed from the morphological chart to actual design alternatives, a choice must be made per function (group) about which design option to include in the design alternative. To aid in this selection process, it is beneficial to evaluate the options on the morphological chart on feasibility. In this way, the best performing options per row can then be theorised into a coherent whole design. This section describes the process of ranking the options on the morphological chart. First, the methodology used in the review is described. Next, the review process itself is discussed and finally the reviewed morphological chart is presented.

5.3.1. Morphological chart review methodology

The options on the morphological chart are rated using a scoring system based on SCOR performance cards utilising the level 1 performance metrics. All function options have been reviewed using an

Table 5.1: A morphological chart of the design options for functions of the supply chain operations, excluding the (digital) coordination system functions.

Function description	Function numbers	Options					
		1	2	3	4	5	6
Receival	1.2, 1.3, 3.3	Pallets	Roll container	Conveyor system	Packages		
Prepare	1.4, 1.5, 3.8	As-is	Repack to custom HD	Repack to standardised HD	Bunching		
Move	1.6, 1.7, 1.10, 2.1, 2.6, 2.7, 3.2, 4.1, 4.4, 5.2	Manual moving	Forklift truck	Electric hand-drawn	Conveyor belt		
Log	1.8, 1.9, 3.6, 4.2, 8.3	On paper	Digital	Barcode	QR	Direct RFID	Indirect RFID
QC	2.2, 3.5	Manual	Computer scan	Sampling			
Dispose waste (production)	2.5, 3.7	Recycling company	Composting	Incinerator			
Sell on spot market	2.8	Auction	Wholesale trader	Local florist(s)	Outlet		
Produce bouquets	3.4	Manual	Automated	Semi-automated			
Store	4.3	Ground floor	Stacked	Environmentally controlled	Internal	External	
(Un-)load vehicle	5.3, 6.3	Manual	Forklift	Electric hand-drawn	Roll on-roll off		
Move vehicle	5.4	Truck	Van	Cargo bike	Car plus trailer	Electric	Fossil fuels
Receive vehicle	6.2	Park nearby	Unloading facilities				
Service vending point	6.4	Cleaning	Remove old flowers	Remove all flowers	Resupply environmental control materials		
Stocking	6.5	Manual	Roll on-roll off	Swap out of HDs			
Dispose waste (vending points)	6.6, 6.7	Local	Contracted separately	Take back with you			
Sell to consumers	8.1	At location	Online in advance based on stock	Online made-to-order			
Provide proof of delivery	8.2	Printed receipt	Digital receipt	Register in consumer account			

adapted version of the SCOR level 1 performance metrics on a performance score card (ASCM, 2022). On such an adapted SCOR performance card, six attributes are reviewed:

- **Reliability:** an attribute of how reliable the function option can perform the task in the supply chain, with a better score for a higher predictable success rate.
- **Responsiveness:** this attribute relates to how quickly the supply chain can perform the task using the option provided.
- **Agility:** for this attribute, the capability of the supply chain to react to disturbances is measured.
- **Cost:** the cost attribute describes the operating costs for performing a function in the supply chain using that particular option.
- **Assets:** this attribute relates to the efficiency of utilising the assets in the supply chain, like capital or transport capacity.
- **Environmental:** an attribute that focuses on the ability of the supply chain to perform its function with minimal environmental impact using this option.

The remaining two performance metrics in SCOR are not used in this study due to the stage of the design. **Profit** would require a more quantitative study to be measured accurately and **Social** as a metric would require the inclusion of the company's social values, which are out of scope for this design for now.
In a traditional SCOR performance ranking workshop, existing supply chains are compared with competitors and potential changes. As this design will be for a non-existing supply chain concept, it is difficult to make a comparison to existing methods or competitors. Therefore, the method used in ranking workshops is not suited for the review of the design options in the morphological chart. To compensate, the SCOR performance ranking method is adapted to be used with a Likert scale scoring. In this scoring system, the impact of a design option will be compared to its alternatives within the function and scored on a scale from **- -** (very poor) up to **+ +** (very good). In this way, the qualitative performance of each design option can still be assessed within the SCOR framework. The advantages and disadvantages of each design option will be listed and based on this, the scores on the Likert scale will be awarded to the options. These advantages and disadvantages are derived from widely used supply chain options and supplemented by discussions about these options with clients and experts.
In order to convert the SCOR performance cards into a reviewed morphological chart, for now all design options will be reviewed to give an initial indication of their level of feasibility. The scores on the SCOR performance cards per row of options will be converted into three categories:

- **Feasible:** options that seem feasible to include in the supply chain design will get a green designation.
- **Conditionally feasible:** options that are not always feasible or do not perform the best, will get an orange designation. Here, options that only work when other choices were made are also included.
- **Infeasible:** finally, options that are too difficult to implement or perform poorly will get a red designation.

5.3.2. Morphological chart review

Based on this methodology, all functions will be reviewed and ranked. For the first function (**Receival**), an example of the taken approach is given here. In this example, the process behind the conversion of the advantages and disadvantages for each option into SCOR performance cards is described extensively to clarify the steps taken. The same process was used to go from the tables of advantages and disadvantages to the SCOR performance cards for the other functions. The results are given in appendix B.

Receival

Table 5.2 displays the options for receival in the morphological chart, along with the advantages and disadvantages related to them. The accompanying SCOR performance cards are given in figure 5.10. Based on this review, a conveyor system was deemed most reliable, followed by roll containers. Pallets are ranked as neutral to balance their high reliability for goods other than flowers and their low

Table 5.2: Advantages and disadvantages of each design option for receival

Option	Advantages	Disadvantages
Pallets	• Lower handling costs • Lower bulk purchase prices • Commonly used for non-flower goods like packaging materials • Fairly reliable as a common method of transport • Reusable	• Difficult transport of flowers and bouquets on pallets • Required development of new storage method
Roll container	• Industry standard method of transporting flowers • Very reliable • Can be used flexibly	• Less space efficient due to wheels
Conveyor system	• Predictably delivers goods to a certain point • Allows for fast transport with limited handling • Efficient usage of assets from a close-by production location	• Feasible only within greenhouses or for internal production • Not feasible for external production • Low flexibility due to fixed construction • Higher operating costs
Packages	• Expansive infrastructure for handling existing • Easy to deliver and process	• Infeasible for the scale of all goods flows entering the supply chain • Not very reusable when combined with organic waste from flowers • Very wasteful due to amount of packaging material required

reliability for transporting flowers. Finally, packages are not reliable at all for flowers due to several disadvantages, especially at a larger scale. For the same reasons, a neutral score for pallets regarding responsiveness is given, with the other options performing better on speed. Roll containers, which are the industry standard, are most flexible to transport flowers due to their versatility. A conveyor system on the other hand is limited by its fixed construction and rated poorly. Packages and pallets are also rated poorly due to their poor performance when transporting flowers. The reusable systems (pallets and roll containers) perform better on costs than a more expensive to operate conveyor system. Using packages is expensive due to the amount of packaging material required for a large amount of flowers. On assets, a conveyor system makes most efficient use of existing facilities, with pallets providing efficient use of storage space. Roll containers score neutral here due to their larger size per volume. Finally, packages score poorly due to the continuous investment required to renew material due to organic waste. To complete, the reusable and space-efficient pallets score best on environmental, with the roll containers and conveyor system scoring neutral. The waste that material produces when using packages leads to a poor score there. Comparing the scores per design option leads to an initial ranking indicating that **roll containers** and **conveyor system** are feasible, **pallets** conditionally feasible and **packages** are infeasible to use.

5.3.3. Reviewed morphological chart

Table 5.3 depicts the result of this review process of the morphological chart by color-coding the cells based on the three earlier described levels of feasibility. Based on this chart, some design approaches can be selected by attempting to combine as many feasible options across all functions. This will be done in the next section.

Pallets		Roll container		Conveyor system		Packages	
SCOR Performance Attribute	Score	SCOR Performance Attribute	Score	SCOR Performance Attribute	Score	SCOR Performance Attribute	Score
Reliability	0	Reliability	+	Reliability	++	Reliability	--
Responsiveness	0	Responsiveness	+	Responsiveness	+	Responsiveness	+
Agility	-	Agility	++	Agility	--	Agility	--
Cost	+	Cost	+	Cost	-	Cost	-
Assets	+	Assets	0	Assets	++	Assets	--
Environmental	+	Environmental	0	Environmental	0	Environmental	--

Figure 5.10: The SCOR performance score cards for the design options for receival.

Table 5.3: A reviewed version of the morphological chart, indicating the feasibility of all design options. Green means feasible, orange means conditionally feasible and red means infeasible.

Function description	Function numbers	Options 1	2	3	4	5	6
Receival	1.2, 1.3, 3.3	Pallets	Roll container	Conveyor system	Packages		
Prepare	1.4, 1.5, 3.8	As-is	Repack to custom HD	Repack to standardised HD	Bunching		
Move	1.6, 1.7, 1.10, 2.1, 2.6, 2.7, 3.2, 4.1, 4.4, 5.2	Manual moving	Forklift truck	Electric hand-drawn	Conveyor belt		
Log	1.8, 1.9, 3.6, 4.2, 8.3	On paper	Digital	Barcode	QR	Direct RFID	Indirect RFID
QC	2.2, 3.5	Manual	Computer scan	Sampling			
Dispose waste (production)	2.5, 3.7	Recycling company	Composting	Incinerator			
Sell on spot market	2.8	Auction	Wholesale trader	Local florist(s)	Outlet		
Produce bouquets	3.4	Manual	Automated	Semi-automated			
Store	4.3	Ground floor	Stacked	Environmentally controlled	Internal	External	
(Un-)load vehicle	5.3, 6.3	Manual	Forklift	Electric hand-drawn	Roll on-roll off		
Move vehicle	5.4	Truck	Van	Cargo bike	Car plus trailer	Electric	Fossil fuels
Receive vehicle	6.2	Park nearby	Unloading facilities				
Service vending point	6.4	Cleaning	Remove old flowers	Remove all flowers	Resupply environmental control materials		
Stocking	6.5	Manual	Roll on-roll off	Swap out of HDs			
Dispose waste (vending points)	6.6, 6.7	Local	Contracted separately	Take back with you			
Sell to consumers	8.1	At location	Online in advance based on stock	Online made-to-order			
Provide proof of delivery	8.2	Printed receipt	Digital receipt	Register in consumer account			

5.4. Design alternatives

To make the step from the reviewed morphological chart to an actual design, it is important to look back at the original concept and the goals that this design should fulfill: the design aims to create a unified supply chain operation shipping flowers after harvest up to sale to consumers in automated vending machines. In this preliminary design study, different approaches to this design can be explored to provide a first review of the options available. This is carried out by postulating four different approaches, in order to cover a wide range of the design space. This is achieved by ensuring that the approaches differ on degree of centralisation, complexity, amount of coordination and timeline of implementation.
The most extensive approach to the concept is a design in which all functions are performed in-house to keep centralisation high. In this approach, maximum control over the supply chain as well as high levels of coordination are present. This supply chain design is compared to other designs with varying levels of coordination. For this comparison, three alternative approaches are proposed to cover a large part of the design space. First of all, a simplified, easy to implement approach is proposed which fulfills the main goal of shipping flowers but does not include high levels of coordination. In the next approach, not the entire supply chain is unified but parts are outsourced by partnering with the existing chain. Finally, an alternative approach is proposed where the vision of a fully unified supply chain is the long-term goal but simplifications are made to ease implementation at this point of time.
In this section, all four alternatives are described and their strategy to select options in the morphological chart is given. Based on this strategy, the best scoring design options per function on the morphological chart are combined into a full design alternative. These options will thus form the physical design of the supply chain for this study. Based on this physical design, a SCOR level 2 mapping (ASCM, 2022) will be made to further clarify operations. A legend for the processes used in the SCOR mapping is given in appendix D

5.4.1. Alternative 1: keep it short & simple

As a first alternative, this design approach foregoes most complexity in the supply chain and will try to keep the operations as simple as possible. Here, the design will mainly focus on getting flowers to the vending locations, without complex planning operations in the background. In this approach synchronization with the production location is no longer a target and customisation is limited. Operations are standardised as much as possible, for example with fewer bouquet options, simplified replenishment and limited dynamic pricing. This would limit the complexity of the central coordination system significantly, which would make the project easier to develop. Whilst this approach strays from the original intention of high coordination for this project, it is interesting to explore nonetheless. Such an approach may well be a good option for an earlier phase of the project to create a market share and it can also be a good choice to start with a simple operation and build complexity step by step starting with this solution. In this design approach, the customer order decoupling point will be located just prior to the consumer purchasing a bouquet from a vending machine. To achieve this strategy of make-to-stock, bouquets are made based on a regular schedule and pushed to the vending points irrespective of actual sales at these locations. A periodic refresh of the full vending locations will thus be done to limit complexity.

Morphological chart

For this design, the selected design options from the morphological chart is given in table 5.17. Their reasoning is given in appendix C in table C.1.

SCOR level 2 mapping & thread diagram

Table 5.4 describes the processes of the second level of the SCOR Model that are being performed in the supply chain for alternative 1. The thread diagram associated with this design is given in figure 5.12. In this SCOR mapping, the order step is omitted as no dedicated order is used for the restocking of the vending points.

Figure 5.11: The reviewed morphological chart of the supply chain design process with the chosen design options for alternative 1 highlighted.

Function description	Function numbers	Options					
		1	2	3	4	5	6
Receival	1.2, 1.3, 3.3	Pallets	Roll container	Conveyor system	Packages		
Prepare	1.4, 1.5, 3.8	As-is	Repack to custom HD	Repack to standardised HD	Bunching		
Move	1.6, 1.7, 1.10, 2.1, 2.6, 2.7, 3.2, 4.1, 4.4, 5.2	Manual moving	Forklift truck	Electric hand-drawn	Conveyor belt		
Log	1.8, 1.9, 3.6, 4.2, 8.3	On paper	Digital	Barcode	QR	Direct RFID	Indirect RFID
QC	2.2, 3.5	Manual	Computer scan	Sampling			
Dispose waste (production)	2.5, 3.7	Recycling company	Composting	Incinerator			
Sell on spot market	2.8	Auction	Wholesale trader	Local florist(s)	Outlet		
Produce bouquets	3.4	Manual	Automated	Semi-automated			
Store	4.3	Ground floor	Stacked	Environmentally controlled	Internal	External	
(Un-)load vehicle	5.3, 6.3	Manual	Forklift	Electric hand-drawn	Roll on-roll off		
Move vehicle	5.4	Truck	Van	Cargo bike	Car plus trailer	Electric	Fossil fuels
Receive vehicle	6.2	Park nearby	Unloading facilities				
Service vending point	6.4	Cleaning	Remove old flowers	Remove all flowers	Resupply environmental control materials		
Stocking	6.5	Manual	Roll on-roll off	Swap out of HDs			
Dispose waste (vending points)	6.6, 6.7	Local	Contracted separately	Take back with you			
Sell to consumers	8.1	At location	Online in advance based on stock	Online made-to-order			
Provide proof of delivery	8.2	Printed receipt	Digital receipt	Register in consumer account			

Table 5.4: A table of the level 2 SCOR Model processes that are used in the supply chain of alternative 1: keep it short and simple.

Supply chain step	Operations process	Planning process	
Suppliers	S2 (source cutlings & bulbs)	P3	P1
	T1 (grow flowers)	P4	
	F2 (for external suppliers)	P5	
	F3 (for internal suppliers)	P5	
Company hub	S2 (source flowers)	P3	P1
	F2 (ship flowers)	P5	
Bouquet making company	S2 (source flowers)	P3	P1
	S2 (source packaging material)	P3	
	T1 (create bouquets)	P4	
	F2 (ship bouquets)	P5	
Vending points	S2 (source bouquets)	P3	P1
	F1 (sell bouquets)	P5	
Consumers	S2 (buy bouquets)	P3	P1

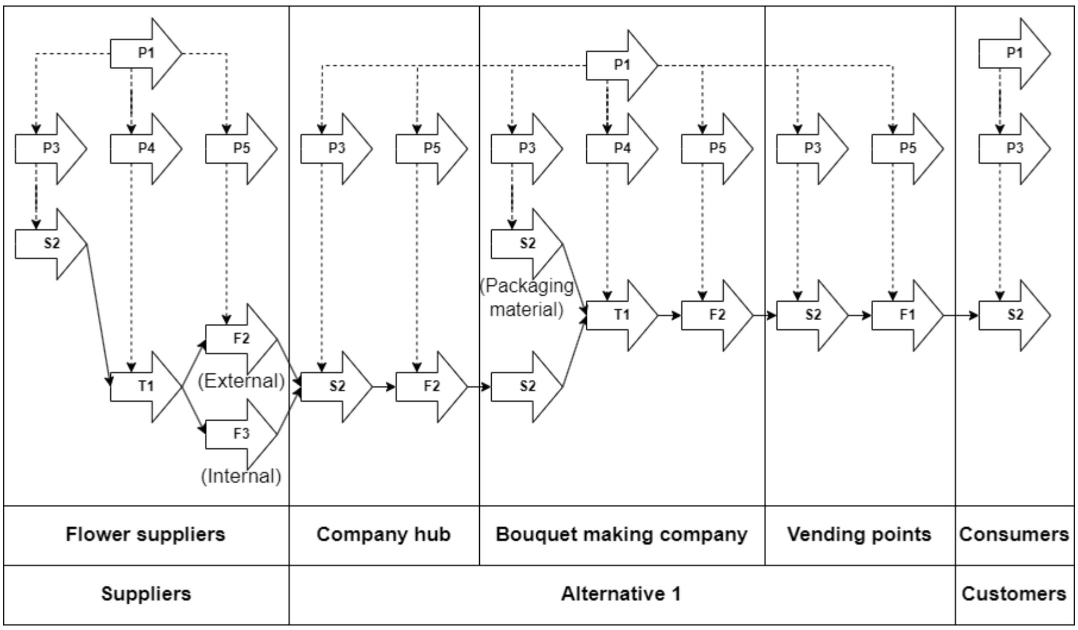

Figure 5.12: A thread diagram of design alternative 1 depicting the level 2 SCOR Model processes in the supply chain.

5.4.2. Alternative 2: centralised and unified operations

For the second alternative, the original concept to create a centralised and unified operation is selected. In this design alternative, maximum control over the supply chain is desired by keeping as many parts of the chain in-house. Such a design would be based on an extensive planning operation, with a powerful central coordination system to keep control of all steps from production all the way to sales. It would be focused on synchronisation of the own accompanying production location with their own vending locations, with a high degree of customisation possible. This option would also include ones own fleet of transport vehicles for operations in the chain to keep maximum control. In this design approach, the customer order decoupling point will be located just before the creation of the bouquet: every bouquet is designed with a specific vending point (as a direct customer of production) in mind. It can thus be perceived as a make-to-order model.

Morphological chart

For this design, the selected design options from the morphological chart is given in table 5.17. Their reasoning is given in appendix C in table C.2.

SCOR level 2 mapping & thread diagram

Table 5.5 describes the processes of the second level of the SCOR Model that constitute the supply chain for alternative 2. The thread diagram associated with this design is given in figure 5.14. It should be noted that for the vending points, the order process **O3** is included as a representation of the synchronisation between the status of the vending points and the bouqueting operations.

Table 5.5: A table of the level 2 SCOR Model processes that are used in the supply chain of alternative 2: centralized and unified operations.

Supply chain step	Operations process	Planning process	
Suppliers	S2 (source cutlings & bulbs) T1 (grow flowers) F2 (for external suppliers) F3 (for internal suppliers)	P3 P4 P5 P5	P1
Company hub	S2 (source flowers) S2 (source packaging material) T1 (create bouquets) F3 (ship bouquets)	P3 P3 P4 P5	P1
Vending points	O3 (order bouquets) S2 (source bouquets) F1 (sell bouquets)	P2 P3 P5	P1
Consumers	S2 (buy bouquets)	P3	P1

Figure 5.13: The reviewed morphological chart of the supply chain design process with the chosen design options for alternative 2 highlighted.

Function description	Function numbers	Options 1	2	3	4	5	6
Receival	1.2, 1.3, 3.3	Pallets	Roll container	Conveyor system	Packages		
Prepare	1.4, 1.5, 3.8	As-is	Repack to custom HD	Repack to standardised HD	Bunching		
Move	1.6, 1.7, 1.10, 2.1, 2.6, 2.7, 3.2, 4.1, 4.4, 5.2	Manual moving	Forklift truck	Electric hand-drawn	Conveyor belt		
Log	1.8, 1.9, 3.6, 4.2, 8.3	On paper	Digital	Barcode	QR	Direct RFID	Indirect RFID
QC	2.2, 3.5	Manual	Computer scan	Sampling			
Dispose waste (production)	2.5, 3.7	Recycling company	Composting	Incinerator			
Sell on spot market	2.8	Auction	Wholesale trader	Local florist(s)	Outlet		
Produce bouquets	3.4	Manual	Automated	Semi-automated			
Store	4.3	Ground floor	Stacked	Environmentally controlled	Internal	External	
(Un-)load vehicle	5.3, 6.3	Manual	Forklift	Electric hand-drawn	Roll on-roll off		
Move vehicle	5.4	Truck	Van	Cargo bike	Car plus trailer	Electric	Fossil fuels
Receive vehicle	6.2	Park nearby	Unloading facilities				
Service vending point	6.4	Cleaning	Remove old flowers	Remove all flowers	Resupply environmental control materials		
Stocking	6.5	Manual	Roll on-roll off	Swap out of HDs			
Dispose waste (vending points)	6.6, 6.7	Local	Contracted separately	Take back with you			
Sell to consumers	8.1	At location	Online in advance based on stock	Online made-to-order			
Provide proof of delivery	8.2	Printed receipt	Digital receipt	Register in consumer account			

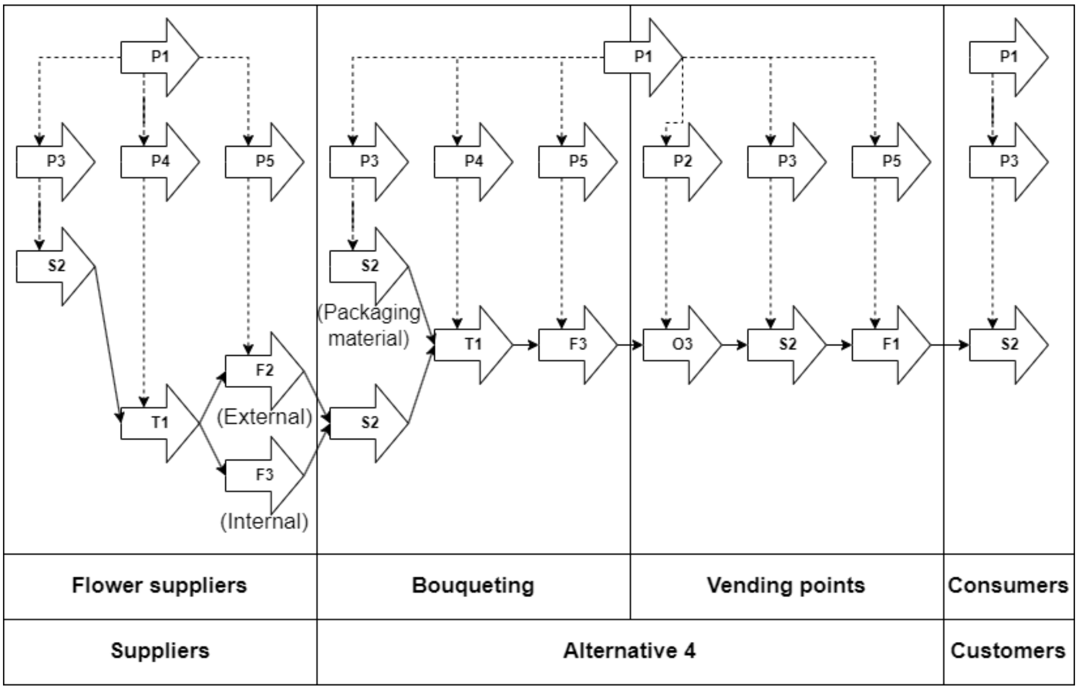

Figure 5.14: A thread diagram of design alternative 2 depicting the level 2 SCOR Model processes in the supply chain.

5.4.3. Alternative 3A and 3B: leveraging the existing chain

The third alternative is designed to be between the other two options: it attempts to fulfil the design intentions of centralised operations without (re-)inventing the wheel in-house for many operations that are already available in the Netherlands. In this design, maximum control of the supply chain is no longer a design target. By partnering with the existing world-class horticulture industry in the Netherlands, their established scale benefits could be leveraged to optimise the efficiency of the project. This would for example include a larger percentage of sourcing from external suppliers, collaboration with existing production locations for bouqueting and transport via external partners. A network of florists will be created who partner in this system and take responsibility for the replenishment of vending points in their specific area. They would see this as an extra service to their customers whereas for the company it offers an attractive partnership to an existing customer base. However, control over replenishment of the vending points remains with the company. This would also allow for flexibility in the complexity of the central coordination system, as operations could start relatively simple, similar to alternative 1, and ramp up in complexity after establishing firm partnerships. For this design, the customer order decoupling point can thus be selected based on the stage at which the design will start. Without detailed selection of the bouquets per vending point, the design can be make-to-stock like alternative 1. This will be elaborated upon in alternative 3A. However, if the bouquets are designated for a specific sales location similarly to alternative 2, this design will be make-to-order. This will be elaborated upon in alternative 3B.

Morphological chart

For this design, the selected design options from the morphological chart is given in table 5.17. Their reasoning is given in appendix C in table C.3.

SCOR level 2 mapping & thread diagram

Table 5.6 describes the processes of the second level of the SCOR Model that constitutes the supply chain for alternative 3. The thread diagram associated with this design is given in Figure 5.16. Here, the order step returns again to indicate the closer connection between the vending points and bouquet production.

Table 5.6: A table of the level 3 SCOR Model processes that are used in the supply chain of alternative 3: leveraging the existing chain.

Supply chain step	Operations process	Planning process	
Suppliers	S2 (source cutlings & bulbs) T1 (grow flowers) F2 (for external suppliers) F3 (for internal suppliers)	P3 P4 P5 P5	P1
Company hub	S2 (source flowers) F2 (ship flowers)	P3 P5	P1
Bouquet making company	S2 (source flowers) S2 (source packaging material) T1 (create bouquets) F2 (ship bouquets)	P3 P3 P4 P5	P1
Partner florists	S2 (source bouquets) F3 (ship bouquets)	P3 P5	P1
Vending points	O3 (order bouquets) S2 (source bouquets) F1 (sell bouquets)	P2 P3 P5	P1
Consumers	S2 (buy bouquets)	P3	P1

Figure 5.15: The reviewed morphological chart of the supply chain design process with the chosen design options for alternative 3 highlighted.

Function description	Function numbers	Options 1	2	3	4	5	6
Receival	1.2, 1.3, 3.3	Pallets	Roll container	Conveyor system	Packages		
Prepare	1.4, 1.5, 3.8	As-is	Repack to custom HD	Repack to standardised HD	Bunching		
Move	1.6, 1.7, 1.10, 2.1, 2.6, 2.7, 3.2, 4.1, 4.4, 5.2	Manual moving	Forklift truck	Electric hand-drawn	Conveyor belt		
Log	1.8, 1.9, 3.6, 4.2, 8.3	On paper	Digital	Barcode	QR	Direct RFID	Indirect RFID
QC	2.2, 3.5	Manual	Computer scan	Sampling			
Dispose waste (production)	2.5, 3.7	Recycling company	Composting	Incinerator			
Sell on spot market	2.8	Auction	Wholesale trader	Local florist(s)	Outlet		
Produce bouquets	3.4	Manual	Automated	Semi-automated			
Store	4.3	Ground floor	Stacked	Environmentally controlled	Internal	External	
(Un-)load vehicle	5.3, 6.3	Manual	Forklift	Electric hand-drawn	Roll on-roll off		
Move vehicle	5.4	Truck	Van	Cargo bike	Car plus trailer	Electric	Fossil fuels
Receive vehicle	6.2	Park nearby	Unloading facilities				
Service vending point	6.4	Cleaning	Remove old flowers	Remove all flowers	Resupply environmental control materials		
Stocking	6.5	Manual	Roll on-roll off	Swap out of HDs			
Dispose waste (vending points)	6.6, 6.7	Local	Contracted separately	Take back with you			
Sell to consumers	8.1	At location	Online in advance based on stock	Online made-to-order			
Provide proof of delivery	8.2	Printed receipt	Digital receipt	Register in consumer account			

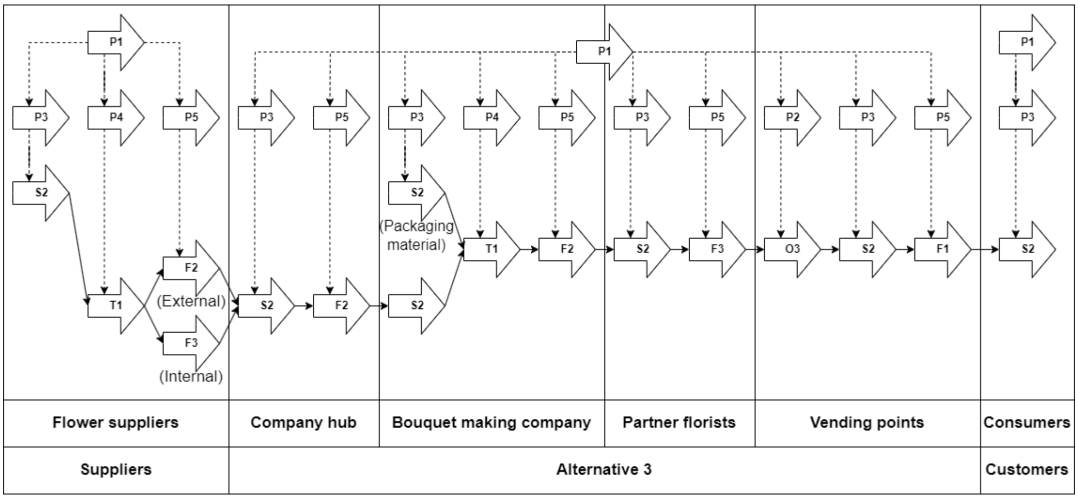

Figure 5.16: A thread diagram of design alternative 3 depicting the level 2 SCOR Model processes in the supply chain.

5.4.4. Alternative 4A and 4B: preparing for growth

In the fourth alternative, the design approach described by alternative 2 is set as a long-term target. Whilst the company aims to reach this approach, such a solution is not immediately feasible in this scenario. In this design, some choices for the supply chain will be based on ease of implementation, for example drawing from alternative 1. However, with this design it should be kept into account that there is a path dependency in the growth of the business. Choices made at this point may help or hamper implementation of later changes to the supply chain design. This design approach should be flexible whilst also providing a stable foundation to build upon at a later stage. Compared to alternative 3, this design approach attempts to maximise in-house control of the supply chain by minimising external partnerships. These activities must otherwise at a later stage be in-sourced, if the company wants to grow towards a centralised and unified chain. The customer order decoupling point in this approach can be located just prior to customer purchase as well, with the intention to move this forward in the chain later on. Such a make-to-stock system is embodied by alternative 4A. It could also start with designated bouquet production for specific vending points, which will make it make-to-order. This design alternative, which starts from a higher base level, is presented as alternative 4B.

Morphological chart

For this design, the selected design options from the morphological chart are given in Table 5.17. Their reasoning is given in appendix C in Table C.4.

SCOR level 2 mapping & thread diagram

Table 5.7 describes the processes of the second level of the SCOR Model that constitutes the supply chain for alternative 4. The thread diagram associated with this design is given in Figure 5.18. In this SCOR mapping, the order step is included to indicate the connection between the vending point performance and the earlier steps in the supply chain process. The resulting SCOR level 2 mapping is similar to that of alternative 2, since the process order is aligned by design. With a similar process alignment, the future growth of the system can be performed without significant changes to the supply chain. It should be noted that the scope of this thesis is limited to SCOR level 2 mapping, whereas changes would appear on level 3 of the SCOR model. For example in alternative 4, S2.1 (Establish order signal) under S2 (source flowers) consists of a fairly repetitive and predictable order schedule. Such a system may use BP.033 (traditional demand forecasting improvement) as a guideline for the process scheduling. However, alternative 2 would require this supply chain process to be far more elaborate, due to the influence of the central demand forecasting as well as actual sales data. Here, BP.014 (Demand planning and forecasting) as well as BP.027 (Pull-based inventory replenishment) would be a better practice for this supply chain process.

Table 5.7: A table of the level 2 SCOR Model processes that are used in the supply chain of alternative 4: preparing for growth.

Supply chain step	Operations process	Planning process	
Suppliers	S2 (source cutlings & bulbs) T1 (grow flowers) F2 (for external suppliers) F3 (for internal suppliers)	P3 P4 P5 P5	P1
Company hub	S2 (source flowers) S2 (source packaging material) T1 (create bouquets) F3 (ship bouquets)	P3 P3 P4 P5	P1
Vending points	O3 (order bouquets) S2 (source bouquets) F1 (sell bouquets)	P2 P3 P5	P1
Consumers	S2 (buy bouquets)	P3	P1

Figure 5.17: The reviewed morphological chart of the supply chain design process with the chosen design options for alternative 4 highlighted.

Function description	Function numbers	Options					
		1	2	3	4	5	6
Receival	1.2, 1.3, 3.3	Pallets	Roll container	Conveyor system	Packages		
Prepare	1.4, 1.5, 3.8	As-is	Repack to custom HD	Repack to standardised HD	Bunching		
Move	1.6, 1.7, 1.10, 2.1, 2.6, 2.7, 3.2, 4.1, 4.4, 5.2	Manual moving	Forklift truck	Electric hand-drawn	Conveyor belt		
Log	1.8, 1.9, 3.6, 4.2, 8.3	On paper	Digital	Barcode	QR	Direct RFID	Indirect RFID
QC	2.2, 3.5	Manual	Computer scan	Sampling			
Dispose waste (production)	2.5, 3.7	Recycling company	Composting	Incinerator			
Sell on spot market	2.8	Auction	Wholesale trader	Local florist(s)	Outlet		
Produce bouquets	3.4	Manual	Automated	Semi-automated			
Store	4.3	Ground floor	Stacked	Environmentally controlled	Internal	External	
(Un-)load vehicle	5.3, 6.3	Manual	Forklift	Electric hand-drawn	Roll on-roll off		
Move vehicle	5.4	Truck	Van	Cargo bike	Car plus trailer	Electric	Fossil fuels
Receive vehicle	6.2	Park nearby	Unloading facilities				
Service vending point	6.4	Cleaning	Remove old flowers	Remove all flowers	Resupply environmental control materials		
Stocking	6.5	Manual	Roll on-roll off	Swap out of HDs			
Dispose waste (vending points)	6.6, 6.7	Local	Contracted separately	Take back with you			
Sell to consumers	8.1	At location	Online in advance based on stock	Online made-to-order			
Provide proof of delivery	8.2	Printed receipt	Digital receipt	Register in consumer account			

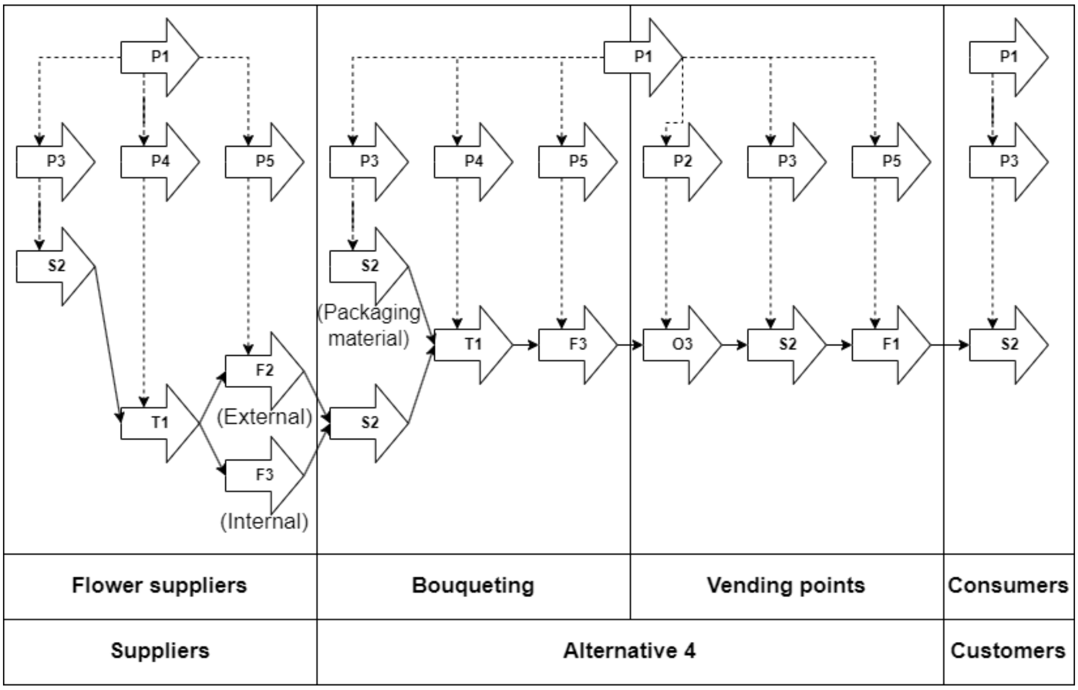

Figure 5.18: A thread diagram of design alternative 4 depicting the level 2 SCOR Model processes in the supply chain.

5.5. Conclusions and contribution of chapter

In this chapter, four design alternatives were created for the physical operations of the supply chain:

- **Alternative 1: keep it short and simple:** a design foregoing most complexity in the chain that attempts to get flowers from receival to the customer as predictable and simple as possible. In this design, high levels of control over the supply chain are no longer desired to limit the complexity of operations. This will be a make-to-stock supply chain.
- **Alternative 2: centralised and unified operations:** in this alternative, maximum control over the supply chain is desired and all operations are performed centralised within the supply chain. As such, while extensive planning and coordination is required, this would lead to a high value product for the consumer. This will be a make-to-order supply chain.
- **Alternative 3: leveraging the existing chain:** for this design alternative, the target is to use the existing world-class logistical network and support infrastructure surrounding the floriculture industry in the Netherlands. As such, control of the chain is partially outsourced to external partners. This design can be both a make-to-stock (3A) and a make-to-order (3B).
- **Alternative 4: preparing for growth:** this approach towards the design aims to set a foundation for later complexity but with a simplified start. As such, it attempts to design the supply chain in a configuration as similar as possible to alternative 2, such that it can grow in that direction whilst postponing some of the more impactful decisions at this point. Such a design could also be both make-to-stock (4A) and make-to-order (4B), depending on the complexity at which operations will commence.

5.5.1. Contribution to the design project

This chapter has converted the concept and the resulting design space into four alternatives for the design of the physical operations of the supply chain. These design alternatives are based on an extensive review of the design space, including a performance score of all options. Based on these physical supply chain designs, a matching digital design will be made for each alternative in the next chapter. Then, also based on the scores given in this chapter, the performance of these alternatives will be ranked in chapter 7 to select the best alternative.

6

Designing the digital systems: enterprise architecture modelling and evaluation

Based on the alternatives created for the supply chain in chapter 5, a design for each accompanying digital system can be created. These digital systems facilitate and assist the central coordination system that is required to organise each supply chain. As each design alternative has a different level of complexity, this inherently translates into differing levels of complexity for the digital systems design discussed in this chapter. To create a clear link between business processes and the IT applications they require, each digital systems design is developed using Enterprise Architecture models. As there is some overlap between the different alternatives, components of the Enterprise Architecture models that have already been discussed for a different design alternative will not be explained again. Any datasets required to enable the digital system to perform its designed tasks will be included in this design, and the complexity of acquiring such data enablers is also discussed.
For each of the alternatives, the development of the Enterprise Architecture models is described first, after which the digital design resulting from the model is discussed. The resulting representations of the models are given in appendix E. Next, the resulting digital designs are given a score by comparing them to each other, after which the chapter is concluded.

6.1. Alternative 1: keep it short & simple

The first design alternative is based on the creation of a relatively simple supply chain operation where a special focus was placed on keeping the complexity as low as possible. In this design, the processing of the supplied flowers into products for consumers is based on the make-to-stock concept. This means that production can be based on pre-determined schedules and bouquet types. As the production is thus predictable and of low complexity, such a process does not require the assistance of a digital system: a simple guidance for the production workers would suffice, informing them on the bouquet types they will produce that day. Slight adaptations in bouquet composition during the production process are also of little concern as they are not made for a specific consumer (or vending machine) in mind.
This design decision for the supply chain also greatly simplifies the ordering process, since this can also be performed on a predictable and adaptable schedule. Thus, there is no need for a digital system in this case well. Finally, the transport process in this design alternative is based on a predictable, scheduled approach in which the types of products are fixed, as well as the routes they take and their corresponding intervals. This business process is therefore also possible without a digital system.
In this design, three services need the support of a digital system: stock keeping, automated vending and payment processing. A stock keeping system is necessary to keep an account of the goods flowing through the system. There are two main reasons for this: accounting, and registration of goods in storage. Whilst stock keeping could in theory be performed on paper without a digital system, much

more efficient off-the-shelf inventory management software can be used for this service with little custom adaptations required. Compared to this increase in efficiency, this is only a small investment in IT complexity.
The automated vending points used in the business model of the company require their own IT system to facilitate both the (re-)stocking and sales processes. This system must be able to provide a sales terminal for consumers as well as a method to register the delivery of new goods into the vending point. In the case of automated vending points that are developed by an external supplier, they come with their own software package that provides these applications. These vending points include their own payment processing technology that is also covered by the accompanying software. An adaptation to the software might be necessary to include the dynamic pricing process. However, as the dynamic pricing is based on time-based markdowns, this adaptation to the vending point software can be of low complexity. For example, an FTP software system can be used to regularly transfer updated pricing lists from the company to the vending point software. This would facilitate the time-based markdowns required for the dynamic pricing in this design alternative.

The resulting Enterprise Architecture model shows that the central coordination of the supply chain is possible with only a low complexity digital system. It is of interest to note that all software components required for the system can be used off-the-shelf. This can be very beneficial when starting the business, since no custom software packages have to be developed. The only potential complexity introduced here is the interface between the dynamic pricing and the automated vending point software. Whilst the creation of such a system is not a complex component, it would require the cooperation of the supplier of the vending point software. In theory, the supply chain could operate without this application component by manually setting prices regularly while an automated solution is still under development. It should also be noted that this digital design requires no data enablers in order for the system to work. For example, since no demand prediction takes place in this model, there is no need for customer demand data. The flip side of this argument is the fact that this system generates little data about the supply chain that could later be used to improve the business. The only external enablers in this model are the software providers of the off-the-shelf packages that will be selected.

6.2. Alternative 2: centralised and unified operations

The second design alternative was developed as an ideal scenario where complexity is no limiting factor and the most expansive supply chain could be established. This is also translated into the accompanying digital systems design: no limitations are placed on the number of software systems, their off-the-shelf availability and the required data enablers.
For such a system, a central coordination platform plays an important role in the supply chain. This system consists of multiple parts working together to coordinate the business processes:

- **Demand forecasting:** this application service provides forecasting of the demand in each vending point per type of bouquet. Such a system would therefore guide the ordering of fresh flowers, as well as the production and transport planning. It is based on two data sets: location demand data and customer demand data.
- **Stock keeping:** the stock keeping application registers the in- and outflow of fresh flowers in the system and their locations along the chain. This system works in close cooperation with the flower tracing system to determine what product goes where. This application would be based on inventory management software.
- **Flower tracing:** here, the source and current location of each (subset of) flowers is traced along the supply chain such that the company and its central coordination platform as well as the final customers can see where the product was sourced from. To facilitate this, barcode and/or QR scanning software can be used to keep track of the flowers in cooperation with the stock keeping software module.
- **Production planning:** in this design alternative, production of bouquets is based on a matching activity between the supplied deliveries of fresh flowers and the expected consumer demand at the vending points. Next to this, the manufacture-to-order approach for order customising will force the production of separate bouquets for these customers as well. The production planning

module of the central coordination platform would thus need to provide the number of bouquets that are required to be restocked for each production run and their composition based on flower types. For this activity, a material requirements planning software package might provide a foundation to build upon.

- **Transport planning:** the centralised and unified operations model envisions transport based on actual necessity instead of a time-based schedule. As production is done for a specific restocking operation, these finished bouquets must be transported to specific vending points. This translates into a variable transport schedule that can be optimised per run, based on current necessity to service a vending point. A transport management system software package can therefore be used to facilitate this part of the central coordination platform.
- **Dynamic pricing:** to create the high level of dynamic pricing that this design alternative envisions, a pricing algorithm must be developed. This algorithm must account for the different factors that influence product value over time and be able to continuously update the price point for the final product displayed to the consumer. Such a pricing algorithm must be custom made for the company to incorporate all relevant factors.
- **Order customising:** the final part of the central coordination platform is a portal in which customers can order their own customised bouquets for purchase at their vending point of choice. Such a system needs to consist of a portal in which the customer can create their own bouquet. Next to this, the customised order must be added to the production planning and, if necessary, specifically ordered.

Outside of the central coordination platform, two other application services are necessary to facilitate this supply chain design. First of all, because of the continuously fluctuating production planning due to updates from the demand forecasting, the orders for suppliers will also be subject to change. Thus, it is desirable to create a digital system that interfaces between the requirements for the production in the supply chain and the systems of suppliers such that the correct products are automatically ordered. Next to this, the expanded focus on customisation and customer interactions means that their corresponding data will also be part of the digital system. Therefore, a customer data management system can be useful to allow for registration of customers. An off-the-shelf CRM system could be sufficient for this part of the digital design.

From the resulting digital systems model, it is immediately obvious that in comparison with alternative 1, this digital systems design has far more components and interconnections. Besides this, the number of components that requires custom development is much larger. The central coordination platform becomes somewhat comparable to a full enterprise resource planning (ERP) software system, consisting of several different disciplines that need to work in cooperation. The implementation of ERPs has long been known as highly complex and has often resulted in failures (Umble et al., 2003). Combining existing components and custom-made components in such a system can thus be seen as a challenging endeavour.

Besides the complexity in the software systems themselves, another challenge is that this digital design is only as good as its predictions. This makes the demand forecasting module especially crucial. The accuracy of this forecast will have a cascading effect on the entire supply chain, from what will be ordered through what will be produced, all the way up to the price and the available stock at the vending points for customers. This system has two important data enablers: customer demand data and location demand data. Without good quality of the underlying data, this crucial module of the system will not function and thus the whole effort of creating a balanced central coordination platform will be in vain. Whilst the acquisition of these data sets is out of scope for this thesis project, it should be noted that this is of vital importance. Next to this, it may also be difficult to gather this data accurately without actually selling to consumers and using that data.

Finally, the inclusion and registration of customer data in the system will come with legal responsibilities about the adequate handling of their personal data. Legislation on this subject has recently become significantly stricter and more enforced, mostly stemming from the European General Data Protection Regulation (Council of the European Union, 2016). This places extra responsibility and considerations on the shoulders of the company when implementing this design option.

6.3. Alternative 3: leveraging the existing chain

The third design alternative was generated to co-exist within the existing logistics systems that already service the floriculture industry. For this, new actors have been introduced in this process in the form of partner companies. Partner transport companies will be made responsible for the shipment of the bouquets whereas partner florists will be responsible for the servicing and stocking of the vending points. In this alternative, two sub-variants are possible: a make-to-stock approach (alternative 3A) and a make-to-order approach (alternative 3B).

For alternative 3A, three components remain of the central coordination platform: the stock keeping system, the production planning and the dynamic pricing algorithm. Their main functionality is similar to that of alternative 2, albeit with significantly reduced complexity due to the make-to-stock operations in the supply chain. This makes the supply chain more predictable and thus requires less central coordination via digital systems.

One new component is added to the central coordination platform: a partnership platform. On this platform, the interface between the company's operations and the partners in the system will be located. Such a system needs to be able to provide clear information to the partners about their obligations. While the detailed design of such a system is not within the scope of this thesis, two initial approaches are proposed. In the first approach an interface is developed with existing software, for example of the transport company of choice. In such a way, the requirements for transport of the company can be added to the existing planning systems of the partner companies. A second approach is to create a more open platform in which orders are placed on a digital marketplace, similar to how the digital platform economy works with companies like Über and JustEat.

For alternative 3B, the demand forecasting module is again included in the central coordination platform to facilitate a make-to-order supply chain, . Together with the actual sales data from the vending points, this module will place the orders in the system so they can be used in planning the production. The inclusion of a functional demand forecasting system thus also requires the inclusion of demand data.

Whilst the other applications in this system still perform similar functions compared to alternative 3A, it should be noted that the shift to make-to-order greatly reduces the predictability of the supply chain. This translates into a more complex application required for the same business processes. Besides including the demand forecasting component, the other application components must therefore be expanded as well, as was also explained under alternative 2.

When reviewing both options, it is interesting to see that the complexity of the digital systems is reduced compared to alternative 2. Especially alternative 3A could be a feasible start for a company with only one complex interaction point: the partnership platform. Other systems in this alternative could mostly be used off-the-shelf. However, for alternative 3B, the complexities introduced by the shift to make-to-order cascade through all supply chain processes, and thus also affect the digital systems facilitating this approach. Custom-created software would then be required for more parts of the digital design. Next to this, the system in alternative 3B relies strongly on the accuracy of the demand forecasting. This makes the data enablers again important in this alternative.

Another point of interest in both alternative 3A and 3B is the reliance on cooperation of the partner companies in the system. Whilst the burden of development of the partnership platform lies with the company itself, the eventual usage and implementation requires effort from the partners. This may be relevant on multiple stages: development of the interfacing software, creation of data sharing agreements, contracting about fees and of course the actual interaction with the partnership platform. The eventual success of this platform is thus influenced by external forces that are outside of the company's control.

6.4. Alternative 4: preparing for growth

As a final design, alternatives 4A and 4B were created to eventually move towards the idealised situation in alternative 2 without immediately requiring high levels of complexity. Whereas the physical supply chain is relatively similar, the digital design of alternative 4 is only based on the philosophy of alternative 2. A central coordination platform is created that oversees some components of the full system discussed under alternative 2 as a basis for future growth in the digital design. Here, these systems do not necessarily require the complexity but can provide a foundation for later growth towards this level of complexity during running operations and with the experience that comes from that. For alternative 4B compared to 4A, the demand forecasting is once again added due to the shift to make-to-order similar to the discussion under alternative 3.

It should be noted that some components in alternative 4A are far less complex than their similar counterpart in alternative 4B. For example, the production planning in a make-to-stock supply chain is predictable and relatively easy to coordinate. With the shift to make-to-order, this predictability becomes far more fluid and affects the coordination of day-to-day activities.
To elaborate on this example, a simple spreadsheet software that divides the existing stock of flowers into suitable bouquets based on a list of compositions can be sufficient to implement as a production planning application in alternative 4A. In the case of alternative 4B, such a system will quickly be insufficient as production will be influenced by actual sales, making the adaptations a continuous process that can be changed up to the moment the current production run is released. In a spreadsheet, this would first of all require active updating of the number of bouquets that have to be produced based on active sales data. Next, the type of bouquet that will be restocked per vending point must be derived from the forecasting software. Finally, this must be integrated with the existing stock of fresh flowers to find the optimal bouquet types to produce. Whilst only a simple example, the difference between both options in complexity is stark and must be clear when deciding between both.
An advantage of alternative 4A with respect to the other alternatives is the fact that data can be gathered from the central coordination platform during active sales. This is something that could later serve as a high quality basis for the data enablers that are required to create a demand forecasting system. Other design alternatives either require this dataset a priori (alternatives 2, 3B, 4B), or are not well-instrumented to generate this data (alternative 1). Considering the importance of acquiring accurate and reliable datasets and the difficulty to accomplish this, as was discussed under alternative 2, this property to allow for the creation of these data enablers makes alternative 4A an attractive design approach .

6.5. Scoring of the designs

Now that all digital designs have been presented, a score for their performance can be given. The digital designs have not been made on a level detailed enough that individual scores for performance of design components can be given such as was done for the physical design options. Therefore, the designs will be scored by comparing the results to each other. Looking back at the design objective and the requirements and constraints, three main targets are relevant to discuss about the digital designs. First of all, the system must be feasible to implement. Next to this, the digital design must be possible to be implemented by a starting company. Finally, the digital systems were aimed to provide a benefit in the coordination of the supply chain, making the whole greater than the sum of the parts. These targets are translated into the following metrics:

- **Complexity:** as a first metric, the complexity of the digital system is ranked. This criteria relates to the difficulty of implementation of the digital design and how much effort it would require during operation. This is ranked from 1 (poor, which corresponds with high complexity) to 5 (excellent, which corresponds with a simple system).
- **Enablers:** this metric defines how easy it would be to roll out the digital system. For this, two aspects of the digital design are evaluated: the amount of required data enablers and the availability of off-the-shelf software components. This is ranked from 1 (poor, which corresponds with large data requirements and custom software development) to 5 (excellent, which corresponds with little to no data requirements and off-the-shelf software).
- **Enhancement:** this metric describes how much the digital system will enhance the operations that the supply chain will be performing. This is ranked from 1 (poor, only provides necessary support for a functioning system) to 5 (excellent, enhances the value that can be created in the system).

In a similar way as with the use of SCOR performance cards, these metrics will also be scored by comparing their performance to each other. The score will be given on the Likert scale as well. Tables 6.1 to 6.3 summarises the discussion of the digital systems design of the four alternatives and displays their scores based on the three metrics.

Table 6.1: A summary of the digital design alternatives and their performance rating in complexity

	Complexity	
	Summary	Score
Alternative 1: keep it short and simple	Low complexity design Interface between vending point software and dynamic pricing	++
Alternative 2: centralized and unified operations	Comparable to a full ERP software system Many connections and components Highly dependent on performance of demand forecasting module	–
Alternative 3: leveraging the exisiting chain	Medium complexity in number of components and connections Complex interaction related to partnership platform	0
Alternative 4: preparing for growth	Low complexity components Some connections, but scalable Lower dependency on digital system performance for the full supply chain	+

Table 6.2: A summary of the digital design alternatives and their performance rating in enablers

	Enablers	
	Summary	Score
Alternative 1: keep it short and simple	All software components available off-the-shelf No data requirements	++
Alternative 2: centralized and unified operations	Many custom-made components High demand on data quality for both customer and location demand data Data difficult to gather prior to implementation Inclusion of personal data with its own legal restrictions	–
Alternative 3: leveraging the exisiting chain	Few custom-made components Lower data requirements Dependent on external cooperation for success of digital system	+
Alternative 4: preparing for growth	Custom-made components of low complexity Lower initial data requirements	+

Table 6.3: A summary of the digital design alternatives and their performance rating in enhancement.

	Enhancement	
	Summary	Score
Alternative 1: keep it short and simple	No data generation Little coordination of the chain	–
Alternative 2: centralized and unified operations	High level of control over the supply chain Provides efficiency Beneficial for customers due to tracing	++
Alternative 3: leveraging the exisiting chain	Some coordination of chain Value for both company and partners Lower direct control due to outsourcing	0
Alternative 4: preparing for growth	Provides foundation for later full ERP software system Data generation included in the design Some coordination of chain at this stage	0

6.6. Conclusions and contribution of the chapter

In this chapter, the physical design alternatives from chapter 5 were converted into accompanying digital system designs using Enterprise Architecture modelling:

- **Alternative 1: keep it short and simple:** this digital system is of low complexity with all software components available off-the-shelf. Due to the limited amount of control, no data requirements are present. The downside of this approach is that it does not produce any data that can be useful later, and the limited control means that only a low degree of coordination is possible.
- **Alternative 2: centralised and unified operations:** here, the digital system is very complex and can be compared to an ERP software system. It requires many connections and components, as well as a high dependency on data to enable demand forecasting to operate properly. It is highly dependent on the performance of this module, making the system vulnerable. This design does however offer very high control and coordination over the chain and can help provide efficiency as well as value for customers.
- **Alternative 3: leveraging the existing chain:** this design is of a lower complexity since lower control is centralised due to the presence of external partners. However, the interaction between this digital system and the systems of these partners can be complex. When this is implemented properly, it can provide value for both the company and its partners.
- **Alternative 4: preparing for growth:** this design has many components but all are of low complexity. Therefore, the performance of the full supply chain is less dependent on the performance of this digital system. The design is also organised to be able to gather data that can be used to improve the system in a later stage, limiting the need for data enablers at this stage. As the system is of a lower complexity, it is not able to provide a full coordination of the chain, as is the case in alternative 2, and thus limits the added value of the digital system at this stage.

The alternatives have been compared to each other, resulting in a score for the performance of the digital designs of the four alternatives.

6.6.1. Contribution to the design project

In this chapter, the four alternatives for the physical supply chain design have been transformed into accompanying digital system designs. Now that both the physical and the digital designs are completed for each alternative, their performance can be rated and they can be compared to find a best alternative, which will be done next chapter.

7
Rating the performance of the design alternatives

In order to assess and evaluate the designed alternatives, they can be compared to each other based on their performance. This chapter will describe this comparison and will evaluate the rating. First, the performance of the physical supply chain will be evaluated using the earlier-used SCOR performance cards. These will be used in a multiple-criteria decision analysis (MCDA). The digital designs and their discussed impact will also be included in the rating. Finally, the result of this MCDA will be discussed and the alternatives are subjected to a SWOT analysis. Based on the MCDA and the SWOT analysis, the most promising design alternative is selected.

7.1. Performance rating methodology

Since each design alternative consists of a functional design for the supply chain and an enterprise architecture design for the digital system, the alternatives can be compared to each other with respect to both of these designs. For the digital designs, the ratings given for the three criteria in the evaluation of the designs in the previous chapter are used. For the physical supply chain, earlier on in the process, the options in the morphological chart were reviewed with the help of SCOR performance cards. The six categories of these cards (reliability, responsiveness, agility, cost, assets, environmental) will also be the rating categories for the physical supply chain in the MCDA. These performance cards provide a Likert-scale based review per functional alternative. By comparing the scores of the selected options for each full design, a multiple-criteria decision analysis is created. For calculation purpose, the Likert scale of **- -** to **+ +** is converted into a numerical scale from 1 to 5. When multiple design options were selected for a single function, the average between these options is included.
Consideration must be given to the impact of each design option on the full design, as this impact is not equally large for all options. For example, a design choice for the proof of delivery has a far smaller effect than the type of propulsion used for the restocking vehicle. For this reason, in the MCDA, a separate weighting column is added. With this, each design option gets a multiplication factor based on its impact rating from 1 (low) to 5 (high). To account for uncertainties, the results of the MCDA are rounded to a single digit. This prevents negligible deviations in the ratings from having a disproportionate influence on the design choices that are based on the MCDA..

7.2. Multiple-criteria decision analysis

Table 7.1 presents the summarised results of the MCDA that was performed on the different metrics. The full calculations and weightings per function description can be found in appendix F.

Table 7.1: The multiple-criteria decision analysis matrix comparing the four design alternatives on the metrics for both physical and digital design.

	Design alternative			
Metric	1	2	3	4
Reliability	4.2	4.3	4.2	4.3
Responsiveness	3.9	3.5	3.7	3.6
Agility	3.7	4.0	3.8	4.2
Cost	3.7	3.6	3.5	3.8
Assets	3.4	3.5	3.5	3.4
Environmental	3.4	3.5	3.3	3.5
Total - physical	3.7	3.7	3.7	3.8
Complexity	5	1	3	4
Enablers	5	1	4	4
Enhancement	1	5	3	3
Total - digital	3.7	2.3	3.3	3.7
Total rating	3.7	3.0	3.5	3.7

7.3. Interpretation of the MCDA results

The MCDA shows the performance of the different design alternatives. In this section, the performance per metric is discussed to interpret the results of the MCDA.

Reliability

Of immediate interest is that all supply chain design alternatives can be seen as very reliable at performing the physical operations. This could be a direct result of the design being based on the flower journey towards a consumer, thus reliably being able to deliver the product to its customer. Alternative 2 and 4 have a slightly higher rating of reliability, which is mainly based in their design decision to produce bouquets in-house manually, compared to the outsourcing of production for the other two alternatives.

Responsiveness

It is to be expected that responsiveness receives the best rating on the short and simple chain of alternative 1, since the complexities introduced by the other alternatives restrict the speed at which the product can be delivered to its customer, thus resulting in lower ratings there. Alternative 3 receives an average rating here, mainly based on some benefits of scale for storage, production and shipping of the existing logistical network.

Agility

The results for agility also nicely reflect the design approaches for the four alternatives. The first alternative is based on the sacrifice of agility for simplicity, while the fourth alternative was created with flexibility in mind. Alternative 4 performs well in this category mostly due to the standardised systems used in the chain. In alternative 3, some functions are highly rated regarding agility while others receive a lower rating due to restrictions created by outsourcing parts of the chain. Finally, it should be noted that the high rating in agility of alternative 2 can only be guaranteed if the entire system performs as intended: it is expected to be vulnerable to unreliable predictions and disruptions. A detailed analysis (including metrics like robustness and resilience) is not within the scope of this design.

Cost

It is interesting to note that the costs of operating the supply chain are lowest for alternative 4, even though it is not the simplest alternative. The main reason for this is that the internal production of alternative 4 is less expensive per unit of product than the outsourcing of bouquet production that is done in the simplest alternative, which is alternative 1. The costs associated with outsourcing also result in the poor rating on cost of alternative 3. It should be noted that this rating only considers operating costs, disregarding the considerable capital expenses that are required to facilitate internal production in the other alternatives.

Assets
Alternative 2 provides the best usage of the company's assets, which is to be expected as it is designed to unify and distribute the tasks in the supply chain within the company. Alternative 3 also receives a high rating on this metric, since it has relatively few assets. The performance of alternative 4 with respect to the company's assets shows that there is room for growth here.

Environmental
Due to their similarities in design approach, the environmental ratings of alternatives 2 and 4 are both quite high since they keep environmental values in mind. For alternative 1, the way the vending points are serviced result in a lower rating due to the increased waste and usage of cheaper fossil fueled transport vans that result from it. For alternative 3, the extra distances involved due to transport between outsourcing locations reduce the rating on certain metrics. For this metric, the main avenues in which improvement is possible for all alternatives are the energy usage for climate controlled storage and the waste of flowers spoiling due to age.

Digital
For the digital systems design, the difference between the first two alternatives is stark: whereas the digital design of the simplified supply chain is very easy to roll out, it will barely enhance the supply chain operations. On the other hand, the digital design for the unified operations alternative is complex and requires many enablers, but it provides large benefits to the supply chain due to the amount of control possible. For the other two design alternatives, the result is more mixed. They require fewer enablers and are less complex, but also provide lower value to the performance of the chain as a whole. It is of interest to note that with this rating method, design alternatives 1 and 4 score the same average whilst being very different in implementation.

Overall observations
It is very interesting to note that in spite of the differing approaches and ratings per metric, the total ratings for the physical supply chains are very close to each other. With such a small difference between the four, it is difficult to select a winner. The difference in scores on the digital design is larger. For example in alternative 2, the physical supply chain is able to perform well but it requires higher initial investments in the digital system which is nicely reflected in the lower score on the digital design. When combining both the physical and digital scores, alternative 1 and 4 turn out to be the best performing approaches. To aid in selecting a preferred alternative, a SWOT analysis is made for all alternatives in the next section as well as a comparison to the constraints and requirements.

7.4. Further analysis of alternatives

In this section, the four alternatives are evaluated using a SWOT analysis as well as a comparison against the constraints and requirements that were created in chapter 4. The results from this analysis can then be combined with the MCDA results to select a best alternative in the next section.

7.4.1. Alternative 1

Figure 7.1 depicts a SWOT analysis of the alternative 1, showing its strengths, weaknesses, opportunities and threats.

Constraints and requirements
Alternative 1 does fit within all constraints set for this design. The simplicity of the physical operations and digital systems makes it easy to implement within a short period. The second criteria can be met by facilitating environmental control at the vending points. It can also be perceived as completed when the quality of the flowers is allowed to decrease during shelf life. This is commercially viable since the dynamic pricing was included in this alternative. C3 (operate from harvest to sales) is guaranteed due to the design space selection, and C4 (communicate demand in advance) is very possible due to the predictability of a full periodic restocking of all machines. Finally, C5 (review of design) will be performed in chapter 8.
Most of the functional requirements have been translated into parts of the functional design. As such, they are completed at least on a certain level. For FR3, the level of traceability is low but within the design it should be possible to know where bouquets and flowers are headed. There is no more

Figure 7.1: A SWOT analysis of the alternative 1: keep it short and simple.

traceability when the bouquets are placed in the vending points however. FR5 (predict consumer preferences), FR9 (predict demand), and FR10 (monitor performance) can be seen as only partially fulfilled as the coordination system is very limited in this design about monitoring sales and demand prediction. Some predictions can be made based on experience of the employees in the supply chain but it is not facilitated or aided in this design alternative. Finally, FR13 (dynamic pricing) is simplified to a linear depreciation model so does therefore not really include individual product characteristics.
Finally, for the non-functional requirements, NR1 (initial investment), NR2 (scalability) and NR3 (flexibility) are met as the designed supply chain allows operations under these restrictions. Whilst one could argue that the simple rules for replenishment fulfill NR4 (have a central coordination mechanism), it cannot be said that the design is data-driven (NR5) or acting based on data (NR6). This design thus fails these two requirements. The remaining non-functional requirements have either been covered in the design space already or allow for sufficient possibilities to implement these requirements in a later design stage out of scope of this thesis project.

7.4.2. Alternative 2

Figure 7.2 depicts a SWOT analysis of the alternative 2, showing its strengths, weaknesses, opportunities and threats.

Constraints and requirements

Alternative 2 completes C2 (shelf-stable at point-of-sale), C3 (operate from harvest to sales), C4 (communicate demand in advance) and C5 (review of design) similar to alternative 1. Completing the first constraint may be more challenging for this alternative as the preparation of both the application components of the digital system as well as the data required to make the predictions can be difficult to do quickly. With sufficient investment, the limit of three years should be possible but it cannot be taken for granted in this approach.
By design, this approach was intended to perform as many tasks as possible in a unified supply chain and thus it can fulfill all functional requirements. This follows from the choices made in the physical supply chain design (such as a logging method that guarantees traceability) as well as from the digital design including many application components for monitoring, predicting and coordinating the chain.

Figure 7.2: A SWOT analysis of the alternative 2: centralized and unified operations.

This does however come with a downside when looking at the non-functional requirements: NR1 (minimal initial investment) is not met. The investment costs of the physical supply chain are high since all tasks are performed centrally, and the complexity of the digital design with its many application components would also come with a high investment cost. Added to this, extensive market research would be necessary to gather a dataset of sufficient quality to guarantee high quality predictions from the start of operations. Next to this, questions can be placed at the effectiveness of this approach on dealing with fluctuations in consumer demand (NR3). The high reliance on internal production is a threat in responding quickly to changes in demand. The multiple-month lead times due to growing times of fresh flowers means that a sudden uptick in demand cannot be met with internal production. However, significant external purchasing of flowers would reduce the brand proposition of locally grown and traceable production that the consumers might value. A reduction in demand that was not correctly predicted on the other hand will lead to overproduction from the internal production that has to be sold off on the spot market for a lower price, thus limiting profitability. The remaining non-functional requirements are met in this design alternative.

7.4.3. Alternative 3

Figure 7.3 depicts a SWOT analysis of the alternative 3, showing its strengths, weaknesses, opportunities and threats.

Constraints and requirements

This design approach fulfills the first three constraints (feasible to implement in three years, shelf stability at point-of-sale, operate from harvest to sales). For C4 (communicate demand ahead of time), it depends on which of the two subdesigns is chosen: make-to-stock or make-to-order. For a make-to-stock design (3A), this communication would not be automated and other processes should be implemented in a later phase to guarantee that this constraint is met. However, for the make-to-order approach (3B), demand prediction does become a part of the supply chain design and thus this constraint can be fulfilled automated. Finally, CR5 (review of design) is again completed in chapter 8.
When looking at the functional requirements, FR3 (traceability) comes to attention. Due to the outsourcing of parts of the supply chain to partners, it can be more difficult to trace every single product along

Figure 7.3: A SWOT analysis of the alternative 3: leveraging the existing chain.

the entire chain. Detailed process arrangements have to be made with partners if this requirement has to be met. Otherwise the lower control over operations at external partners can create difficulties with respect to traceability. FR11 (transport planning), FR12 (transport trips) and FR14 (vending point servicing) will be outsourced to a partner in the chain and should therefore be fulfilled, but not internally in this design. The other functional requirements are met by their inclusion in the functional design in this study.
For the non-functional requirements, the outsourcing helps with the minimal initial investment (NR1) and allows for scalability (NR2). NR3 (flexibility) is of concern for this approach due to the dependence on external partners. Whilst company operations may be capable to adapt to fluctuations in consumer demand, it is not guaranteed that all partners are able to act similarly quickly. Therefore, the requirement for flexibility can only be met when this is adequately agreed upon and contracted with the external partners. NR4 (central coordination mechanism), NR5 (data-driven approach) and NR6 (act based on data) depend on the subdesign chosen within this alternative. For the make-to-stock approach (3A), the performance compared to these requirements will be limited. The digital system in this subdesign will not act based on data and does not have a data-driven approach to the initial supply chain operations. However, it is possible to grow and adapt the digital design at a later stage to include more capabilities for predicting, coordinating and monitoring. When a make-to-order approach (3B) is chosen, the digital system already includes components fulfilling these requirements in order to be able to perform its make-to-order restocking of vending points. The remaining non-functional requirements are met similar to the previous approaches by the set-up of the design space.

7.4.4. Alternative 4

Figure 7.4 depicts a SWOT analysis of the alternative 4, showing its strengths, weaknesses, opportunities and threats.

Constraints and requirements

When comparing this approach to the requirements and constraints established in chapter 4, first of all it can be seen that the first three constraints are met. The supply chain design is purposefully made to ease implementation. Shelf stability is guaranteed by the inclusion of environmental control in the

Figure 7.4: A SWOT analysis of the alternative 4: preparing for growth.

vending points, whilst the design space was selected to keep the production location and points of sale in mind. For the fourth constraint, demand communication ahead of time is not automated in alternative 4. It should therefore be noted that internal processes in the company should be created to facilitate these demand predictions manually. Such a process can be based on time-series demand forecasting using the data gathered by the consumer sales in the supply chain. Finally, the expert review will be performed in chapter 8.

The functional requirements have been the basis of the functional design so most are inherently fulfilled due to the limits of the design space. Some notes can be place at FR5 (predict and monitor consumer preferences) as well as FR9 (predict demand per location). As the consumer demand prediction is a target to implement in a later phase in the advised design approach, full accuracy cannot be guaranteed initially. These functional requirements have to be fulfilled using more traditional methods in the meantime compared to the way florists currently predict their consumer demand. Consumer preferences are monitored based on sales data in this system. Demand per location is going to be based on this sales data as well, indicating a trigger for restocking when a sale has been completed.

For the non-functional requirements, alternative 4 matches well with a low initial investment (NR1) and scalability (NR2). It also scored best on supply chain agility and thus is suited for the required flexibility (NR3). NR4 (central coordination), NR5 (data-driven approach) and NR6 (act based on data) are covered by the digital system that has been designed for the system. Whilst not being optimal yet, this digital design should provide sufficient capability to perform operations. NR8, NR9 and NR10 are part of the design space so they are covered as well. Finally, the design offers sufficient possibilities for implementation of the processes required for NR7 (quality control standards), NR11 (pricing strategy) and NR12 (bouquet options). The details of these processes however are outside of the scope of this thesis project.

7.5. Best alternative

Based on the MCDA, the SWOT analyses and the review of the alternatives against the constraints and requirements a conclusion about the feasibility of the alternatives can be made and a best alternative can be chosen. The MCDA gives alternatives 1 and 4 the best scores. From the review of constraints

and requirements, it was found that alternatives 3 and 4 meet or partially meet all requirements listed. Alternative 1 fails here due to the limited added value of the coordination system and alternative 2 mainly on the high investment costs.
The SWOT analyses show that alternative 4 offers low operating costs similar to alternative 1, as well as an advantage by being able to start binding consumers to the brand early. This alternative also has an advantage in flexibility in the initial roll-out phase compared to alternative 3 as the supply chain is not partially outsourced. Alternative 1 is less able to provide a clear path for growth in quality instead of quantity compared to the fourth approach. Alternative 2 has the strongest strengths but is also hampered by the most severe weaknesses and threats, making this a risky approach to follow.
To conclude, the fourth approach (preparing for growth) performs best on both the physical supply chain as well as the performance of the digital design. For the physical supply chain, it scores best on the agility and the costs related to the operations. The digital design is also balanced in score: limited in complexity and required enablers whilst also providing value for the operations. It meets or partially meets all constraints and requirements set for the design. From the SWOT analysis, it was found to provide a good combination of early moving advantage and low costs with sufficient room for growth later. As such, it can be advised as the desired alternative for development of the supply chain.
Alternative 4 had two subdesigns: make-to-stock and make-to-order. To assess between these subdesigns, it is relevant to compare the trend for the performance metrics if one of the two was chosen. There would be marginal difference in the physical operations, but the digital systems design would be substantially different. The make-to-order approach (alternative 4B) would require more enablers and introduce more complexity in the digital system design, which would not be compensated at this point by the added value for the supply chain. As such, a make-to-stock approach (alternative 4A) would currently provide the best value for the company as the reduced complexity of the digital design would outweigh the value lost at this point. Moreover, alternative 4A creates a foundation to start a supply chain that can later be developed to be make-to-order when such a step would be feasible for the company. As such, the final advised design approach would be alternative 4A: make-to-stock preparing for growth.

7.6. Conclusions and contribution of chapter

In this chapter, the performance of the design alternatives was compared to each other. From this, the following was concluded:

- In the MCDA, all design alternatives score similarly well on their performance for the physical supply chain in spite of differences in distribution of points over the criteria.
- The inclusion of the digital design in the MCDA lead to alternatives 1 and 4 receiving the best scores.
- When comparing the design alternatives to the constraints and requirements, alternatives 3 and 4 both met or partially met all requirements. Alternative 1 fails on the capabilities of its central coordination system. In this design, it could not create a way for a future as a data-driven business concept. Alternative 2 failed on the initial investment costs related to the high number of internal operations performed physically as well as the complex digital system that has to be custom-made.
- From the SWOT analyses of all alternatives, it can be concluded that alternatives 1 and 4 share their strength in low operating costs and ease of roll-out to market. Alternative 3 lacks in flexibility due to the presence of external partners. Alternative 1 is limited in growth potential in quality and alternative 2 provides the best value but at the cost of some severe weaknesses and threats, making it a risky approach.
- Based on these evaluations of the design alternatives, it is concluded that the fourth approach (preparing for growth) is the best performing alternative. Within this design, the make-to-stock approach would outperform the make-to-order subdesign, making the final advised design approach alternative 4A: make-to-stock preparing for growth.

7.6.1. Contribution to the design project

In this chapter, the physical and digital design alternatives created in chapters 5 and 6 were compared in performance and against the constraints and requirements that were originally posed for the design. Based on this, a best alternative was selected that can be the advice of this thesis project to answer the design objective of the project: a feasible design of physical operations and digital systems for a unified supply chain for a starting floriculture business concept using automated vending points.

8

Demonstrating and evaluating the design: simulation and validation workshop

The final step in the design process will be demonstrating the design. By demonstrating the results of the design process, it can be shown that the resulting artefact works for addressing the problem (Johannesson & Perjons, 2021). This demonstration of the artefact can also communicate the results of the design process, amongst others to the clients in this project. Whilst a real-life experiment with the design would of course be best to demonstrate the validity, this is unfeasible within the scope of this project. Similarly, quantitative modelling is also not an option. Therefore, for demonstration two approaches are chosen: simulation and a validation workshop.

First of all, the working of the design will be demonstrated by simulating the process. This will be done by once again following the flower journey using the rich picture approach. In this way, the design approaches can be converted from functions and options into a visualisation of the physical flow in the supply chain.

For validation and evaluation, a workshop will be held with clients to discuss the artefact that was developed and review its sufficiency for addressing the problem. This will be an ex ante evaluation of the design approaches. The simulations of the design approaches will be used in the workshop for communication about the design. In the workshop, all design approaches will be presented without the associated performance ranking. In this way, the attendees will have the option to give their unbiased evaluation about the alternatives. Besides evaluating the advised design alternative, in this way the performance ranking process can thus also be validated.

This chapter will first address the simulations of the design alternatives, and the approach taken to the creation of the rich pictures. Next, it will describe the setup of the validation workshop and the goals. Finally, the results of the workshop will be discussed and a reflection on these results compared to the internal review process will be made.

8.1. Simulation of the design approaches

The goal of demonstrating an artefact according to (Johannesson & Perjons, 2021) is to show how the developed artefact addresses the explicated problem. For this, the different design approaches are simulated as a flower journey along the supply chain using the rich picture approach. For all four alternatives, these can be found below in figures 8.1 to 8.4. These rich pictures demonstrate the journey of the flowers by visualizing the different steps and how these activities are performed. By comparing these rich pictures, differences in the design approaches can be clearly identified: for example, the inclusion of partners in alternatives 1 and 3 becomes clear by the coloured marked segments of the chain. The rich pictures demonstrate that for each design alternative, the flowers that are received will be taken through a process leading to sale to the end consumer.

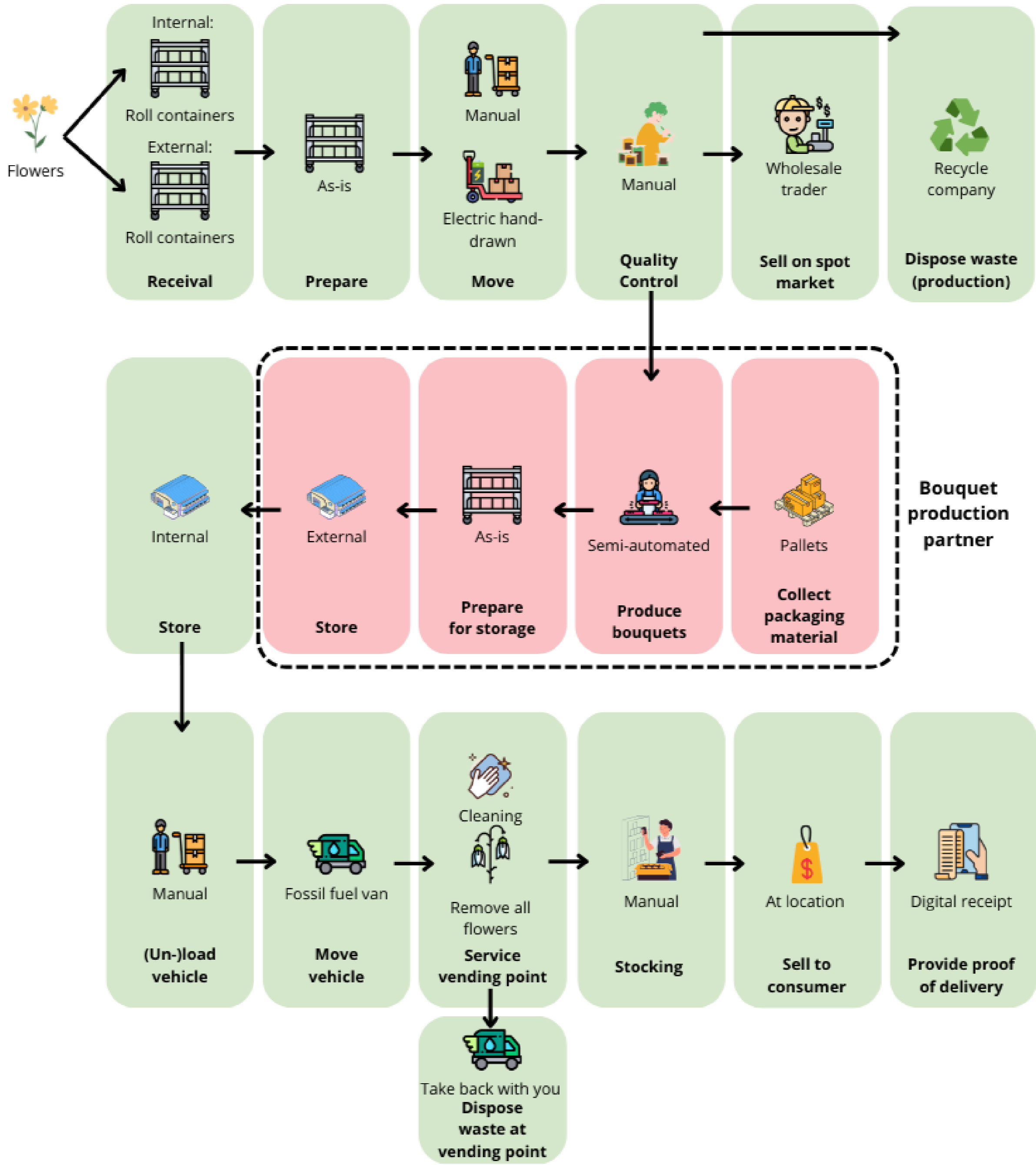

Figure 8.1: A rich picture detailing the flower journey for design alternative 1: keep it short and simple.

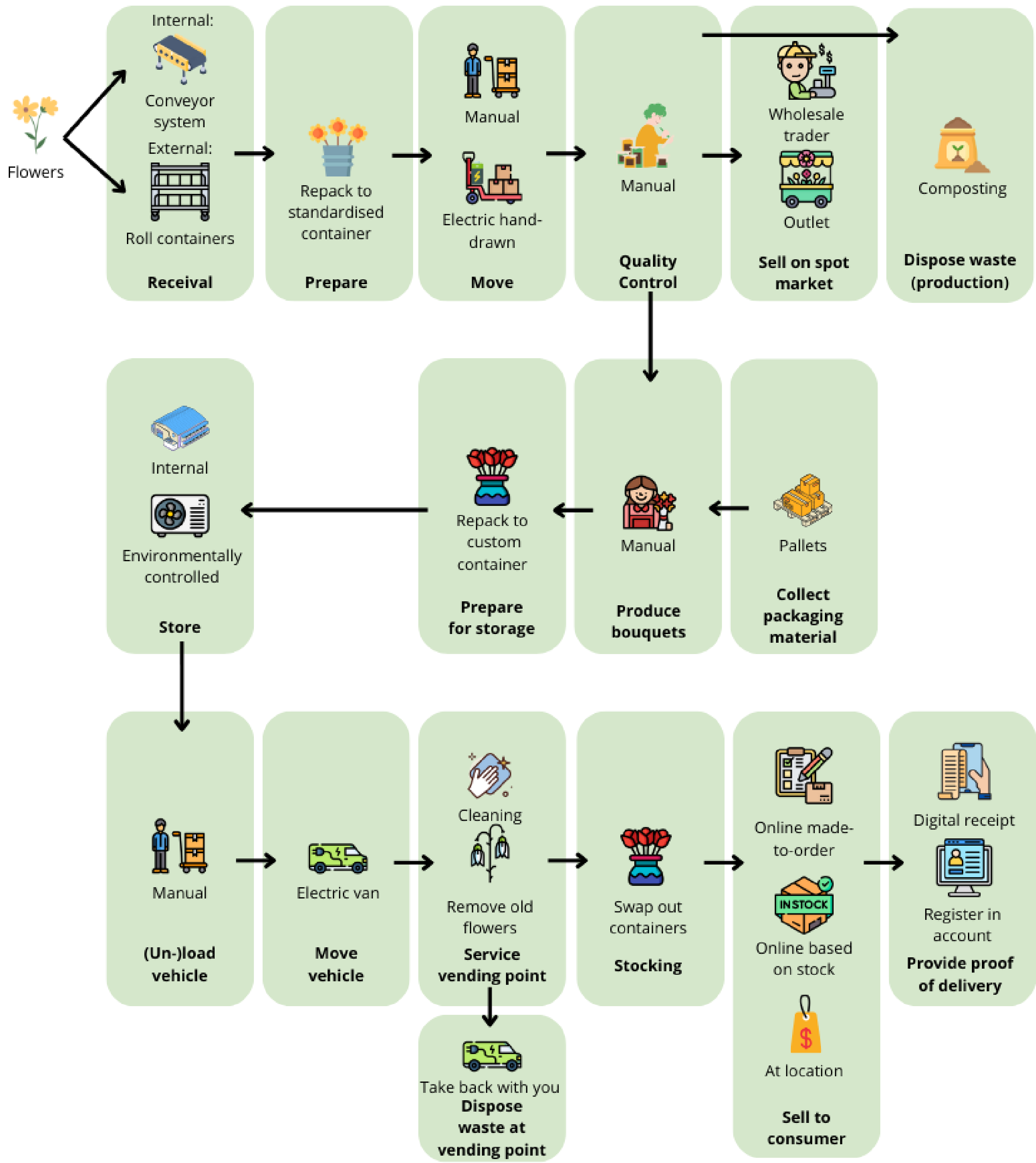

Figure 8.2: A rich picture detailing the flower journey for design alternative 2: centralized and unified operations.

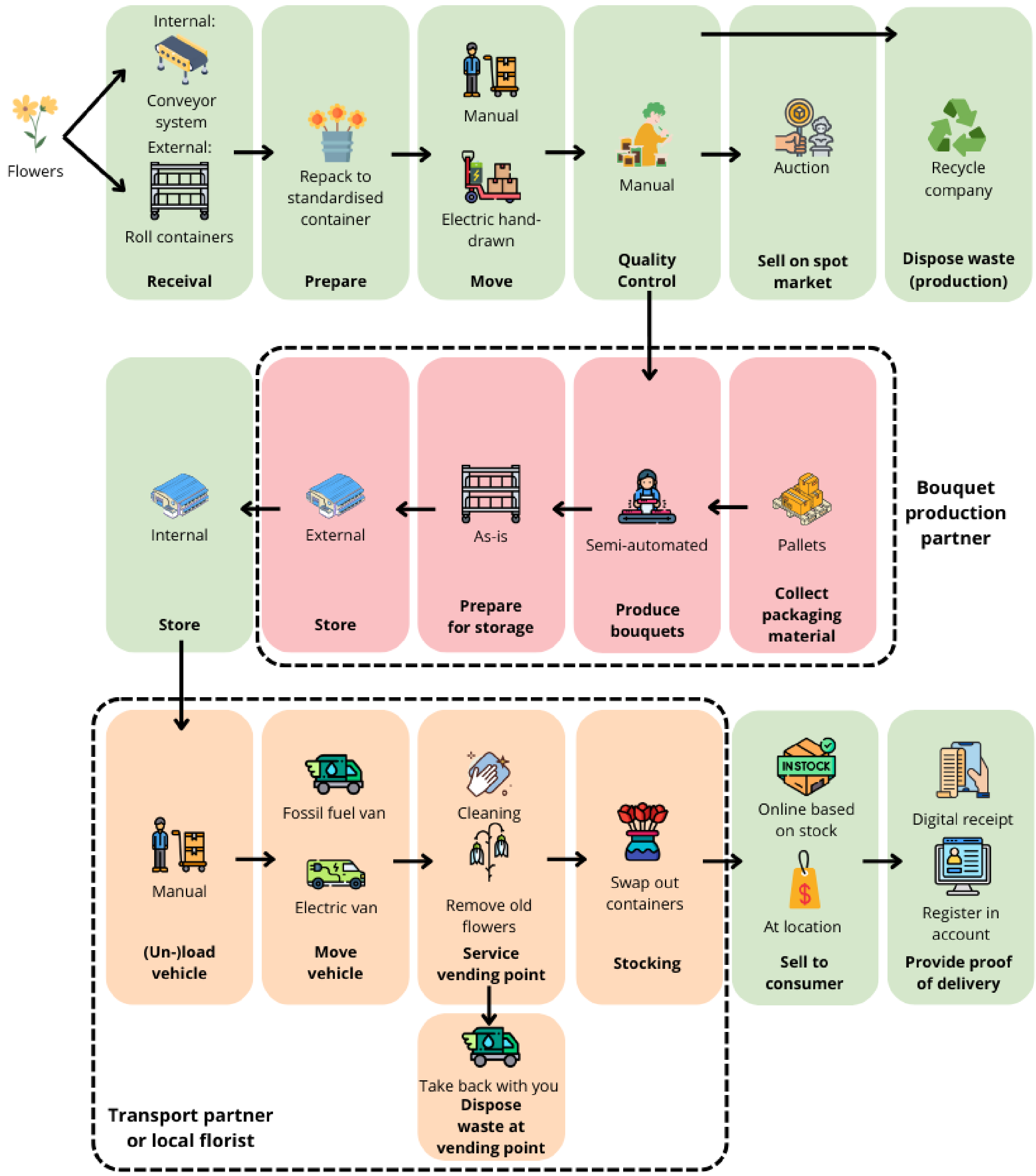

Figure 8.3: A rich picture detailing the flower journey for design alternative 3: leveraging the existing chain.

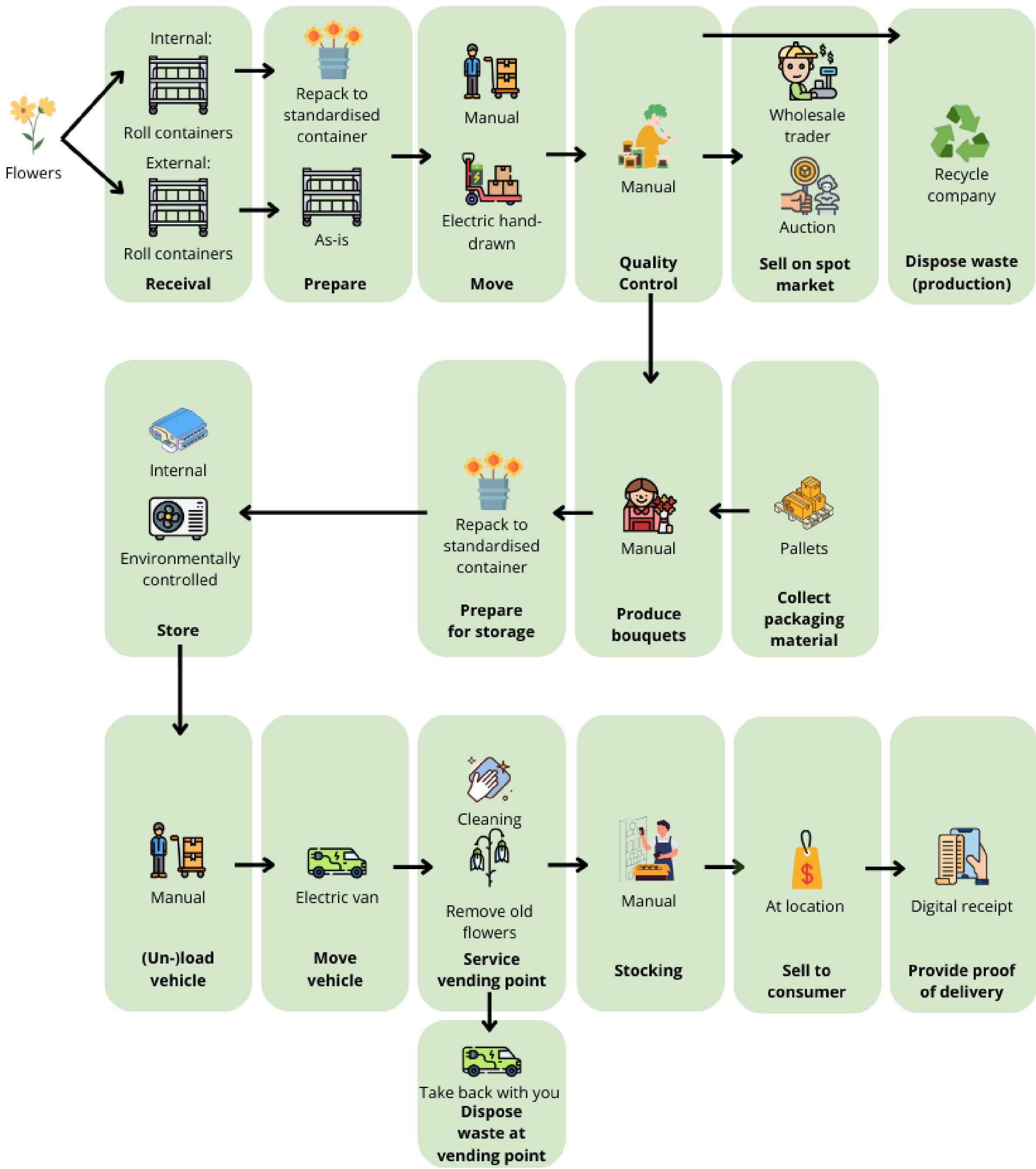

Figure 8.4: A rich picture detailing the flower journey for design alternative 4: preparing for growth.

8.2. Workshop setup

In order to evaluate the design, a validation workshop was organised. Here, by discussion with clients, the design results can be commented upon. This feedback can then also be used for recommendations in a later stage of implementation of this concept, but fall out of scope for this thesis project.
Based on the design evaluation strategy by (Johannesson & Perjons, 2021), this workshop will be an:

- **Ex ante evaluation:** the design is not implemented yet, but will be discussed beforehand with the attendees. This is the only feasible option at this point due to limitations in scope of this project. Such an evaluation will be of low cost and provide benefits for the later process of the development of the artefact by including the feedback from the evaluation. However, it should be noted that this feedback is based on a preliminary version of the artefact and thus provides the risk of bias and false positives due to wishful thinking.
- **Formative evaluation:** the evaluation will be used to improve later steps in the design process. Whilst the scope of the design as set out in this thesis is presented as complete, more detailed design steps that were left out of scope for this project need to be implemented at a later stage. As such, the design will not be a finished prototype and the evaluation will help guiding later evolution thereof.
- **Naturalistic evaluation:** the evaluation will be based on discussion between the presenter and the attendees. The alternative (artificial evaluation) would require a working model of the design, which was deemed out of scope of this project.

To guide discussion about the design, the workshop will be divided in three phases: problem introduction, design demonstration and performance ranking. These phases will be elaborated upon below.

Problem introduction

Duration: 15-20 minutes
To begin the workshop, the problem will be introduced to the attendees by sketching the context that the design will operate in. Even though the attendees are expected to possess knowledge about the floriculture industry, they may not all be on the same level. This phase aims to provide an understanding for the attendees about the challenges that the design is aiming to address, as well as the goals of the design. This phase will be mostly informative to the attendees, whilst questions may be asked for clarification. Discussion is not a target at this phase.
In this phase, the design process will also be briefly explained to show how the problem introduced earlier will connect to the designs that will be demonstrated later. Here, it is also clarified that the supply chain will be the focus of the design and the leading design element for the later digital systems design. The expected output of this phase will be understanding about the context of the design such that informed discussion can take place later on. Any remarks about this context will be noted to be evaluated afterwards.

Design demonstration

Duration: 20-25 minutes
After the introduction of the goals of the design, the results of the design process described in this thesis can be presented. To start, the design approaches described in section 5.4 will be used to introduce the reasoning behind the design alternatives. Next, for all design alternatives, both the physical and the digital design will be presented to the attendees. The physical design will be presented using the rich picture simulations created in this chapter, whereas the digital design will be created by guiding the attendees through the enterprise architecture models of the designs.
During the presentation of the design alternatives, informed arguments gathered during the design process will be shared with the attendees by the presenter. These will however be limited to individual design options by choice: this is done to try to prevent bias by spoiling overall results about the designs that have been gathered in this thesis project. As such, the informed arguments aim to help the attendees in forming their opinions about the alternatives without guiding them to a final result.
After each design has been presented, a moment will be taken for discussion about the benefits and drawbacks of each approach. This will be noted as output from the workshop. In case discussion is limited, some prepared open questions about the design can be asked by the presenter to stimulate engagement. The goal of this phase is only discussion about the design alternatives, not actual review of their performance, which will be performed in the next phase.

Performance ranking

Duration: 15-20 minutes

As a method to gather feedback from the workshop based on the design alternatives, the attendees will be asked to rank the performance of the four options presented during the previous phase. To achieve this, the 9 metrics used in the performance ranking in chapter 7 will be used. These metrics and their definitions and criteria will be explained in detail in this phase as well.

These metrics will be rated per design by the attendees on a Likert scale from 1 (worst) to 5 (best) by comparing the alternatives to each other. All attendees will receive a paper ranking form such that they can provide their evaluation independently. The results from the attendees will then be gathered by the presenter and an average result will be calculated.

The averaged output of this ranking exercise will be discussed with all attendees, for which discussion is invited. If they would like, attendees can personally introduce their own ranking and compare these to the presented average but the presenter will not address individual results to prevent desirable voting behaviour. The results of the ranking workshop will then also be compared with the results found in this thesis project, providing a final round of discussion. The workshop is wrapped up with room for questions and final comments.

8.3. Workshop results

The workshop was performed on the fifth of April 2024. Three persons were present during the workshop to evaluate the designs. Unfortunately, due to scheduling and confidentiality issues no external experts were available to join. Their names and professions are listed in table 8.1 In this workshop, the three phases discussed earlier were performed. Due to the knowledge of the guests, the problem introduction phase could be completed faster than expected. A lot of attention however was given to the design demonstrations, where the attendees found the visual representation of the rich pictures provided in this chapter very helpful. Some differences in understanding between the attendees of the Enterprise Architecture models could be noted, which was apparent due to the difference in number of questions and subjects about this. However, sufficient understanding to continue to the performance ranking exercise was deemed to be present to be able to continue to this phase.

The performance ranking went faster than expected, which was mainly caused by the smaller group of attendees than originally attended. That allowed for quick reactions to questions about the process and specific tasks in the rating of the alternatives. The averaged results of the rankings given by the attendees is given in table 8.2.

8.3.1. Comparison with internal review

The results of the supply chain ranking workshop were very interesting compared to the internal review and ranking using the MCDA described in chapter 7. First of all, it should be noted that all design alternatives gathered quite similar overall scores. This indicates that, based on these criteria, all designs could be comparably feasible. Feedback from the participants directly indicated that this would not be the case in their opinion, but that the limited capability for ranking in such a workshop would not allow them to provide their full feedback. This is part of the set-up of the workshop, which was chosen to be feasible in a relatively short time. When a longer evaluation would have been possible, more criteria or constraints could have been added that might have lead to different results.

Among the feedback from the participants was that in their regular business experience, cost and cash investment criteria often come with hard restrictions attached to the design space. Such constraints

Table 8.1: Attendees of the supply chain ranking and evaluation workshop given on the fifth of April 2024.

Name	Experience
T. Kester	35 years as a grower of multiple plant types
	Former owner of multiple florists
Dr. Ir. J. Westra	27 years working at Priva
	12 years as strategic business developer
R. Kester	Managing director at e-Flora
	Previously business unit manager at SuperFlora BV

Table 8.2: The average score given by the attendees in the supply chain design ranking workshop.

	Design alternative			
Metric	1	2	3	4
Reliability	3.7	4.0	3.3	3.3
Responsiveness	4.0	4.0	3.7	3.0
Agility	3.3	4.3	3.0	3.7
Cost	3.0	2.3	3.0	3.3
Assets	3.7	1.7	4.3	3.7
Environmental	2.7	4.0	3.7	3.3
Total - physical	3.4	3.4	3.5	3.4
Complexity	4.0	2.3	3.0	2.7
Enablers	4.0	3.3	3.7	3.7
Enhancement	2.3	4.3	2.3	2.7
Total - digital	3.4	3.3	3.0	3.0
Total score	3.4	3.4	3.3	3.3

were not included in the workshop for sake of clarity and brevity. In their opinion, the low scores which are also present in the ranking for alternative 2 would in practice lead to a cancellation of this option due to the high cost involved.
Next to these observations, it is interesting to note the difference between the ranking results and the MCDA in table 7.1. Whilst detailed scores differ, some outliers are comparable between both tables. This is, amongst others, present for the low score on costs and complexity for alternative 2, the low environmental performance of alternative 1 and the high responsiveness of this alternative. Notable differences appear in the final ordering of the alternatives. This is mainly caused by the difference in scores for the digital systems. In the workshop, similarly to the MCDA, the supply chain performance resulted in very comparable scores. On the other hand, the digital systems are ranked differently by the attendees of the workshop than in the MCDA performed earlier.
Two main differences are identified which cause a large part of the difference between the two reviews. First of all, the workshop participants rank the complexity and difficulty of gathering the enablers as less severe than was concluded in this internal review. This can be partially caused by their earlier experience with implementation of similar projects. However, when looking at the level of individual scores, a bias of the clients towards a favorable design alternative could also have caused this difference. The second difference is in the perceived complexity of alternative 4 (preparing for growth). In the internal review, this alternative was seen as an approach with a relatively high number of application components which were each relatively simple compared to other options. As such, these components could then later be expanded in complexity. A possible explanation for the difference in scoring between the workshop and this conclusion could thus be that the shortened representation using enterprise architecture models did not fully convey the difference in complexity. In such a model, an application component is represented as a box in the figure without a direct indication of how ”complex” such an application would be. A different explanation might be that the internal review underestimates the complexity involved in the number of connections required between the components, thus also explaining the score difference.
Combined, these differences are the main cause of the differing conclusions between the MCDA (highest scores for alternatives 1 and 4) and the workshop (highest scores for alternatives 1 and 2). The result of two highest scorers in the workshop ranking exercise was also discussed during the workshop. As was mentioned before, the attendees expressed that they had insufficient possibilities in the ranking system to disqualify alternative 2 due to cost. About alternative 1, they mentioned that this would seem as the best option when looking at only the design of the supply chain from receival of flowers up to sale to consumers. However, the attendees noted that this option would be less preferable if the scope of the supply chain design would be expanded to include a production partner, or when certain corporate values like sustainability and quality of product were more important. In such an occasion, their preference was predicted to go for alternative 4. As such, the workshop evaluated the supply chain

designs both in the limited scope of this design study as well as within a wider scope that would be present during implementation and it was found that multiple design alternatives were feasible within the different conditions.

8.4. Conclusions and contribution of chapter

In this chapter, the design alternatives were simulated and a validation workshop was held. This demonstrated and evaluated the designs. The following was concluded:

- The physical supply chain operations were demonstrated by simulating the flower journey using rich pictures. These have shown that the designs are able to complete the supply chain from receiving fresh flowers to selling them to consumers.
- A workshop was held for the clients to evaluate the designs. In this ex ante, formative and naturalistic evaluation process the designs were demonstrated and ranked by the attendees.
- Some differences and similarities between the results of the workshop and the internal review are present. First of all, the rankings for the physical supply chain are again very comparable to each other. Next, two main differences were noted between the internal review and the workshop. First, the complexity of alternative 2 was ranked less poorly in the workshop than in the internal review. This could be caused by earlier experience with such large-scale projects, or bias from clients towards a favourable design alternative. Next, the complexity of alternative 4 was ranked more poorly than in the internal review. A possible explanation for this could be that the internal review underestimated the complexity in the connections between the components, or the representation in enterprise architecture models did not fully convey the lower complexity of application components in this design alternative.
- The ranking method used in the workshop had to be of limited complexity for the sake of clarity and brevity. This unfortunately resulted in attendees noting that some more detailed opinions about the options could not be fully represented in their scores. Of notable interest is the opinion that in their regular business experience, criteria on cost and cash investments would rule out alternative 2.

8.4.1. Contribution to the design project

This chapter has demonstrated and evaluated the design alternatives that were generated in this project. As such, the method framework that this design study has now been completed, leaving evaluated designs that can be the foundation for both actual implementation as well as later scientific study for more detailed design.

9

Conclusion, discussion, limitations and recommendations

In this chapter, the thesis project and its design study are concluded. The results of the study are wrapped up in a conclusion listing the key findings. Based on this, a discussion of the implications of the study is performed and the main limitations of the approach are listed. Finally, several recommendations for future research and implementation in practice are given.

9.1. Conclusion

Objective

In this thesis project, a design study was performed that aimed to investigate the feasibility of establishing a unified supply chain linking production locations and consumers in the floriculture sector. Such a supply chain concept could help meet challenges facing the floriculture sector. This sector has high competition from production in developing markets, and desires to make a shift towards more sustainable and local production. Priva, an expert company specialised in smart horticulture, provided the inspiration for such a unified supply chain with a proposal that included automated vending points for use in the sale to consumers. The thesis project had the following design objective:

> *Develop a design for both the physical operations as well as the supporting digital systems for a unified supply chain that is feasible to implement by a starting floriculture business concept using automated vending points.*

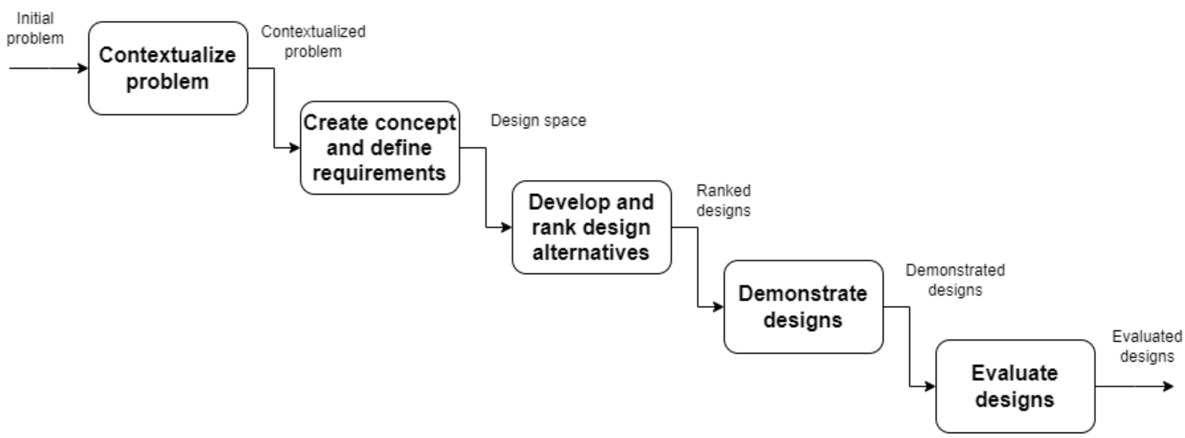

Figure 9.1: A method framework for design science research (adapted from (Johannesson & Perjons, 2021)).

Approach

To perform the design study, the five-step approach given in figure 9.1 was used to convert an initial problem into evaluated designs. First of all, the problem that was initially sketched was contextualised with interviews and a literature study. Based on this, a concept was created for the unified supply chain. This concept was used to create constraints and requirements to limit the design space. Next, design alternatives were created. To create these alternatives the physical supply chain design was viewed as leading, with its operations serving as a basis for the configuration of the digital systems design. For the physical designs, the concept of the unified supply chain was transformed into a functional design and this functional design was the basis for a morphological chart. This chart was reviewed using an adapted version of the SCOR performance scoring cards, and high-scoring options on the chart were combined in four different approaches to span a wide range of the design space. These four design alternatives were expanded upon in more detail using SCOR level 2 mapping. Using enterprise architecture modelling, a digital systems design was created for all four alternatives as well. These alternatives were rated using a multiple-criteria decision analysis, an assessment against the constraints and requirements, and with the use of SWOT analyses. All designs were demonstrated by simulating the flower journey in a rich picture approach. These demonstrated designs were finally evaluated in a workshop with the client to include their feedback on the feasibility.

Key findings

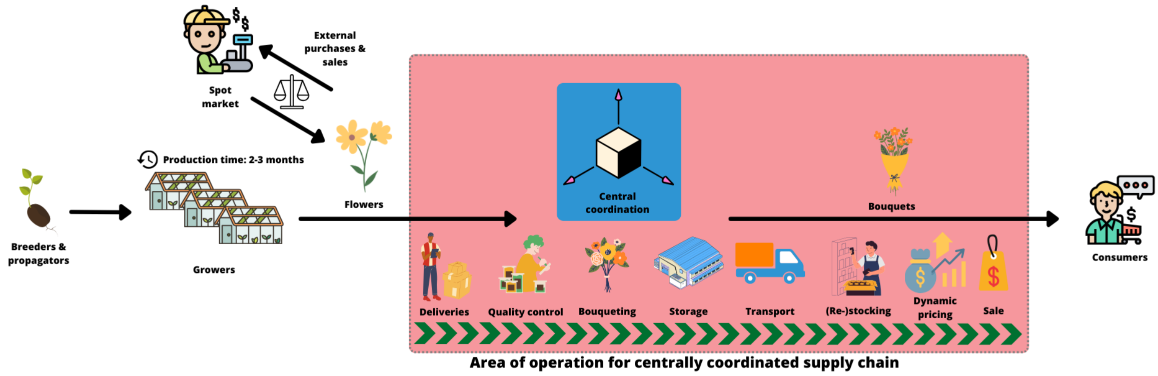

Figure 9.2: A rich picture detailing the flower journey in a unified supply chain.

The supply chain design of a unified and centralised system was conceptualised to consist of eight functions, linking freshly harvested flowers to the consumer. This chain is shown in figure 9.2. Based on this concept, the following four design alternatives were created:

- **Alternative 1: keep it short and simple:** this design prioritizes simplicity throughout the supply chain, aiming to provide a predictable and straightforward journey for flowers from harvest up to the customer. In this approach, the focus shifts away from seeking high levels of control over the supply chain to minimising operational complexity. The supply chain operates on a make-to-stock basis. The digital system in this design is also of low complexity, utilising off-the-shelf software components and lacking any data requirements. However, a drawback of this approach is that it does not produce data, thus limiting future improvement possibilities.
- **Alternative 2: centralised and unified operations:** in this alternative, the focus is on attaining maximum control over the supply chain by centralising all operations within it. Although this necessitates extensive planning and coordination, it provides a high-value product for the consumer. The supply chain operates on a make-to-order basis. The accompanying digital system is very complicated, resembling an ERP software system, with numerous connections and components. It heavily relies on data to enable accurate demand forecasting, making the system vulnerable to the performance of this forecast.
- **Alternative 3: leveraging the existing chain:** in this design alternative, the aim is to leverage the pre-existing world-class logistical network and support infrastructure of the floriculture industry in the Netherlands. Consequently, some control of the supply chain is delegated to external partners. This design supports both make-to-stock (3A) and make-to-order (3B) operations. The associated digital system is relatively simple due to reduced central control requirements. However,

integrating this system with those of external partners may introduce complexities. If implemented effectively, this integration could provide value for both the company and its partners.

- **Alternative 4: preparing for growth:** this design approach lays the groundwork for future complexity while starting with a simplified foundation. It aims to configure the supply chain similarly to alternative 2, enabling growth in that direction while deferring impactful decisions. This flexible design can accommodate both make-to-stock (4A) and make-to-order (4B) operations, depending on initial complexity. Although the digital system design comprises multiple components, each is of low complexity, reducing the dependency of the overall supply chain performance on the digital system's performance. The design also facilitates data collection for future system improvement, with data utilization currently restricted to minimise complexities. However, the digital system's added value is currently limited due to simplifications in this stage.

The performance of these design alternatives was compared based on a multiple-criteria decision analysis (MCDA), by assessing the result against the constraints and requirements and with the use of SWOT analyses. This review resulted in the conclusion that alternative 4, with the make-to-stock approach, is the best performing alternative.
By simulating the flower journey, the physical supply chain design was demonstrated. The demonstrated designs were evaluated in a workshop with clients. This workshop confirmed the feasibility of all design options. No clear winning alternative originated from the ranking performed in this workshop.
As such, this design study has resulted in four evaluated design alternatives that could be used to implement a unified supply chain in the floriculture sector for a business concept using automated vending points. Based on the review, a design in which the aim is to control all processes but with a simplified start is advised as the best option to implement in a feasible manner. This leads to the conclusion that such a design completes the design objective set out for this thesis.

9.2. Discussion

At the start of this thesis project, it was established that it was valuable to investigate the feasibility and challenges related to the implementation of a business concept with a unified supply chain in the floriculture sector. From the design study, which was based on an initial proposal by Priva, it is concluded that the implementation of such a unified supply chain is feasible. However, while full centralisation and unification of control in the supply chain was found to be feasible in the long term, the study also indicated that it is not realistic to implement in full extent directly.
As shown by the evaluation of the capabilities of alternative 2, centralised and unified operations, such a direct implementation of all aspects of the proposal comes with very high costs and a high amount of complexity in the digital systems design. It also requires enablers in data that cannot currently be adequately provided. Therefore, this design study recommends an alternative that is feasible to implement on the short term.
This situation could be different when the unified supply chain is not implemented by a new company but by an existing business, which already possesses a certain level of control over their supply chain and has already gathered data about consumer demand during operations. When these parts of the digital system design do not have to be built from scratch, the accompanying costs and complexity is reduced significantly. This could make the creation of a unified supply chain in the spirit of alternative 2 more feasible on the short term.
Next to this, the unified supply chain could also be implemented without the inclusion of automated vending points. If more traditionally manned storefronts are used to sell to consumers, more active feedback can flow through the chain from these points-of-sale towards the central coordination system. This could for example be in the form of an information flow from the manual ordering process performed by store clerks. Such a system requires less automation along the chain and thus results in a lower complexity of the digital system. On the other hand, a system that relies on manual ordering as a main source of data is difficult to match with a system that incorporates customer demand prediction for production, given that a lead time of three months is required for production.
In this thesis project, a data-driven business model incorporating a unified supply chain has been presented that can be used in a novel field. The project demonstrates its feasibility in the floriculture sector, in which no instance of a similar data-driven unified supply chain has been found. The project has shown that this approach is feasible and can thus be interesting to pursue for economic growth in the sector as well as to meet the current challenges that sector is facing.

Other industries could take a similar approach to verify the feasibility of this design. While directly implementing a fully unified approach from production to sales can be challenging, it is feasible, especially if a longer time is used to establish all parts of the unified chain. To suit the production needs for other industries, the physical supply chain designs may be slightly adapted while the link from production towards automated vending points may be taken as-is. Moreover, the digital systems design is more independent of product type: here, fewer adaptations need to be made to create a concept suitable for other industries.
From a design science perspective, the combination of physical supply chain design and digital systems design has shown that the enterprise architecture methodology is a suitable approach to integrate digital systems into traditionally less IT-focused design studies. As enterprise architecture models inherently attempt to transform business processes into application services and components, it could be applied smoothly on this design study.

9.3. Limitations

Limitations are present with respect to the result of this study due to choices made in the process. They are listed here.
In this design study, the design space was covered using four different approaches that represented a wide range of directions. However, due to time limitations these four representations were not an exhaustive review of combinations of design options from the morphological chart. Other design approaches to the unified supply chain were thus missed and could have provided an interesting alternative solution to the design objective.
It could be interesting to see the result of this digital systems design if a similar approach to the physical design was taken. As it was outside of the scope of this thesis, neither a design space nor requirements were established for the digital design. This possibly results in a digital design with a higher bias than a design that is created following the aforementioned methods. Because of this, it is possible that a larger part of the design space is overlooked. For the review of the options on the morphological chart, the SCOR method was adapted in this thesis to make up for the inability to compare with competitors. This method provided criteria and guidelines on how to score the performance, although it was not a perfect match for all design options. For example, when design options with minor differences in their impact on the environment were compared, it was difficult to give a representative score on this criteria. In such cases the small impact difference could not be represented well on a simple five-point Likert scale, which was used in the development stage of the design study. For later studies, a more detailed scoring method that allows for more nuance could provide finer results.
The workshop to evaluate the design that was organised in this project was performed with only clients in spite of efforts to invite external experts to join. This means that the result of the evaluation may have been influenced by client bias about the desired success of the concept. A fully independent, external expert review could provide a more neutral evaluation of the designs created in this project.
Finally, this study has focused on the qualitative design of the supply chain. As such, no calculations about costs or investments were made. Besides this, the processes in the supply chain were only explored as concepts, not with a quantity attached to them. This was necessary as the available quantitative data was of insufficient accuracy to include in the design project. If more accurate information is available, a more quantitative study can be performed to offer conclusions about feasibility of design options with more certainty. Finally, a quantitative study can be used as well to act as a basis for a modelling approach to demonstrate and evaluate the designs.

9.4. Recommendations

After this thesis project has completed its design and advised an approach for the supply chain to be implemented, some recommendations can be made.

Recommendations for future research:

- From an scientific perspective, it may be interesting to see if an approach starting from data and making supply chain facilitating leads to a different result than this design did. In this thesis project, the choice was made to start with the design of the physical chain and create a digital design facilitating the physical operations. When the project would be approached from a digital angle, it would need to start with a design space exploration for the digital system. The resulting digital design would link to the supply chain and would then necessitate physical operations which would facilitate the movement of goods. Of interest would be both what this would lead to for the physical as well as for the digital design.

- The concept of a unified supply chain producing, shipping and selling a varied product range in automated vending points can be applicable to other industries as well. The recent consumer trends to prefer locally sourced goods can help empower these concepts. It would be of interest to study if the flower journey would be possible with a different product type in the current design, or that large changes have to be made.
- The design alternative that came out best in this design study can be a basis for a more detailed design study, where the step from qualitative to quantitative design can be made. Here, more detailed processes can be investigated and the existing SCOR mappings can be used to make a mapping on a deeper level of the SCOR method.
- This design study took the proposal made by Priva for a unified supply chain in the floriculture sector as a foundation and therefore included automated vending points. A similar study can be made with a different type of sales channel, for example via more traditional stores. With such a channel, fewer parts of the supply chain have to be automated which limits the requirements on the digital system that has to be supporting the physical operations.

Recommendations for implementation in practice:

- As was mentioned earlier, a supply chain design that prepares for growth towards a fully centralized and unified supply chain is best to implement at this phase of the project. This would allow Priva to implement an approach that is easy to roll-out and has a relatively low initial investment.
- A start should be made in preliminary data gathering about consumer demand. Even though no active demand prediction is part of the advised alternative, the novelty of sales via an automated vending point make predictions based on traditional sales uncertain. By starting as soon as possible with market investigations and consumer demand surveys, a head start can be made when rolling out the system.
- Besides the location of the production location, locations of key components of the system (hub, vending points, eventually partners) have to be determined to make a clearer picture of the system. This supply chain design is based on qualitative reasoning as insufficient clarity existed to proceed towards quantitative modelling. In order to accurately design to a higher level of detail, more decisions about the whole chain need to be completed.
- Related to this point, no clear division between internal and external sourcing of fresh flowers has been made in quantity. Whilst some preliminary numbers were shared about the internal flows, it is still to be seen during the startup phase if all harvested flowers can be sold via the automated vending points. Besides, the bouquets have not been designed in detail and thus no clarity exists about the types of flowers that have to be sourced externally as these are not grown in the internal production location. These decisions can even lead to starting the sale of flowers using the vending machines before the production facility is online, which would seriously change the lead times in the system. For later design steps, this should be kept in mind.

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A

Power-interest grid

The Power-interest grid of all actors in the system can be seen in figure A.1.

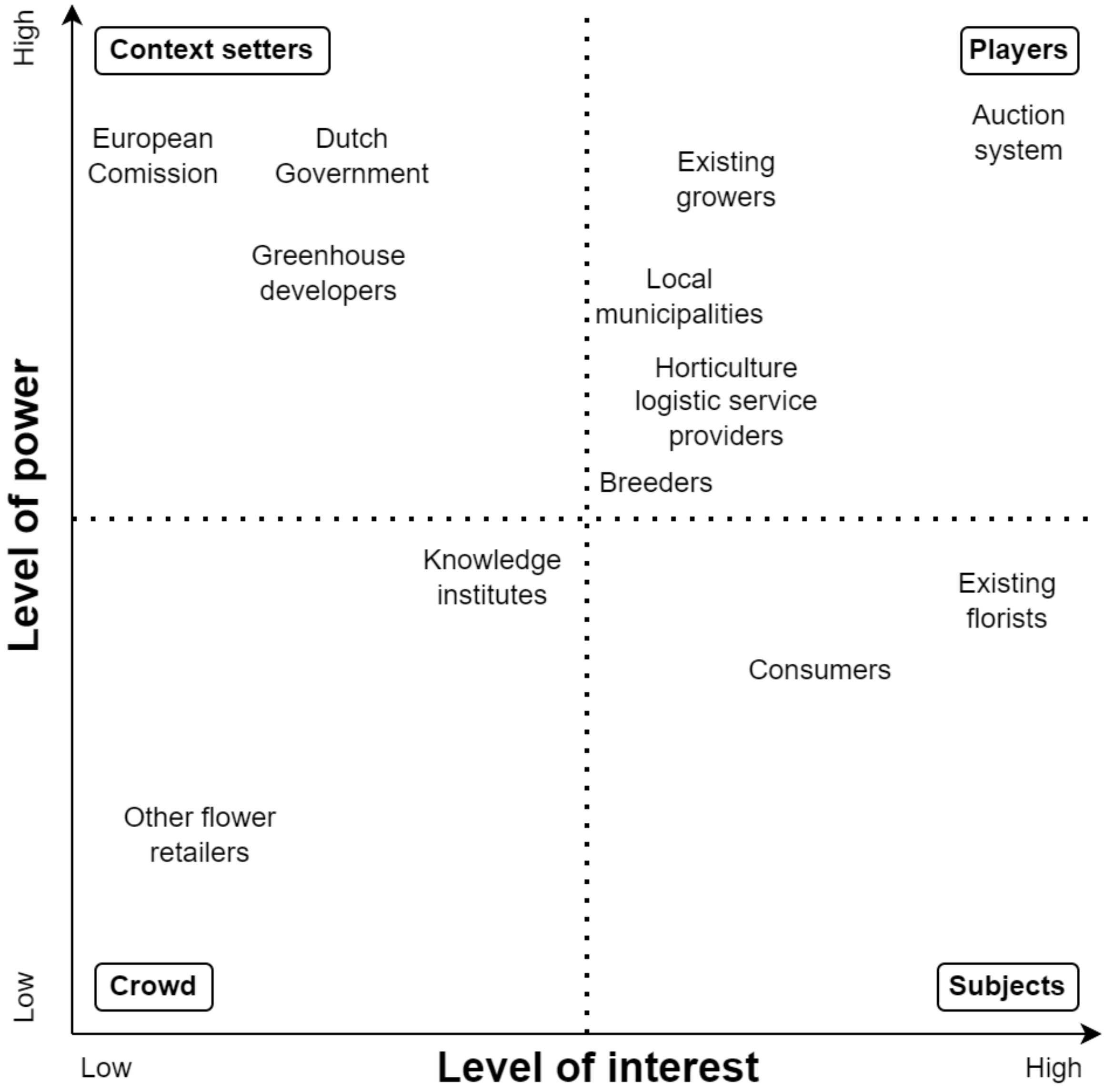

Figure A.1: A power-interest grid of the actors and their power and interest in the system where the business concept will operate.

B

Review and ranking of options on the morphological chart

This appendix lists a review and ranking of all functions in the morphological chart using the methodology described in section 5.3.

Receival

Table B.1: Advantages and disadvantages of each design option for receival

Option	Advantages	Disadvantages
Pallets	• Lower handling costs • Lower bulk purchase prices • Commonly used for non-flower goods like packaging materials • Fairly reliable as a common method of transport • Reusable	• Difficult transport of flowers and bouquets on pallets • Required development of new storage method
Roll container	• Industry standard method of transporting flowers • Very reliable • Can be used flexibly	• Less space efficient due to wheels
Conveyor system	• Predictably delivers goods to a certain point • Allows for fast transport with limited handling • Efficient usage of assets from a close-by production location	• Feasible only within greenhouses or for internal production • Not feasible for external production • Low flexibility due to fixed construction • Higher operating costs
Packages	• Expansive infrastructure for handling existing • Easy to deliver and process	• Infeasible for the scale of all goods flows entering the supply chain • Not very reusable when combined with organic waste from flowers • Very wasteful due to amount of packaging material required

Pallets		Roll container		Conveyor system		Packages	
SCOR Performance Attribute	Score	SCOR Performance Attribute	Score	SCOR Performance Attribute	Score	SCOR Performance Attribute	Score
Reliability	0	Reliability	+	Reliability	++	Reliability	--
Responsiveness	0	Responsiveness	+	Responsiveness	+	Responsiveness	+
Agility	-	Agility	++	Agility	--	Agility	--
Cost	+	Cost	+	Cost	-	Cost	-
Assets	+	Assets	0	Assets	++	Assets	--
Environmental	+	Environmental	0	Environmental	0	Environmental	--

Figure B.1: The SCOR performance score cards for the design options for receival.

Prepare

Table B.2: Advantages and disadvantages of each design option for prepare

Option	Advantages	Disadvantages
As-is	• Easiest and cheapest option • Good cost-effectiveness • Responsive when receival and moving options align, requiring minimal preparation	• Conditionally feasible; relies on alignment of receival and moving options • Limited applicability if preparation is necessary
Repack to custom HD	• Utilizes custom handling device if beneficial later in the supply chain • Advantageous for asset usage if custom HD is beneficial	• Costs of custom HD may not justify benefits if not useful later in the chain • Responsiveness can be slightly better than a standard HD
Repack to standardised HD	• Utilizes stackable Dutch flower bucket, a standard HD in the industry • Great interoperability with other partners in the supply chain • Prevents purchase costs of HDs due to borrowing system • High interoperability enables advantageous agility	• Plastic-based solution
Bunching	• Improves later handling of flowers	• Unnecessary if proper HD is sufficient for later steps in the supply chain • Wasteful if not necessary • May require additional time and resources for bunching process

As-is		Repack to custom HD		Repack to standardised HD		Bunching	
SCOR Performance Attribute	Score	SCOR Performance Attribute	Score	SCOR Performance Attribute	Score	SCOR Performance Attribute	Score
Reliability	+	Reliability	+	Reliability	+	Reliability	+
Responsiveness	++	Responsiveness	+	Responsiveness	0	Responsiveness	-
Agility	-	Agility	--	Agility	++	Agility	+
Cost	++	Cost	--	Cost	+	Cost	0
Assets	0	Assets	++	Assets	+	Assets	-
Environmental	+	Environmental	-	Environmental	0	Environmental	-

Figure B.2: The SCOR performance score cards for the design options for prepare.

Move

Table B.3: Advantages and disadvantages of each design option for move

Option	Advantages	Disadvantages
Manual moving	• Reliable option for operations, especially for shorter distances. • Advantages in cost as no equipment is required. • No restrictions on where one could go	• Limited to shorter distances. • Not very fast
Forklift truck	• Proven reliable concept for pallets • Can be quite fast	• Mostly limited to usage with pallets • Expected limited number of pallets used for other material does not warrant the purchase of a forklift truck • High energy usage due to size
Electric hand-drawn	• Feasible for larger unit handling and longer distance travel • Aids in flexible movement of goods while keeping operational complexity low • Advantage in responsiveness due to easier moving compared to other options	• More expensive than manual movement
Conveyor belt	• Fast delivery of goods on the belt	• Not reliable for transporting different types of flowers simultaneously • Limited to fixed destinations • High operating costs

Manual moving		Forklift truck		Electric hand-drawn		Conveyor belt	
SCOR Performance Attribute	**Score**	**SCOR Performance Attribute**	**Score**	**SCOR Performance Attribute**	**Score**	**SCOR Performance Attribute**	**Score**
Reliability	++	Reliability	+	Reliability	+	Reliability	0
Responsiveness	0	Responsiveness	+	Responsiveness	++	Responsiveness	+
Agility	+	Agility	0	Agility	++	Agility	--
Cost	++	Cost	--	Cost	0	Cost	--
Assets	0	Assets	--	Assets	+	Assets	+
Environmental	+	Environmental	-	Environmental	0	Environmental	0

Figure B.3: The SCOR performance score cards for the design options for move.

Log

Table B.4: Advantages and disadvantages of each design option for log

Option	Advantages	Disadvantages
On paper	• Proven method	• Infeasible for digital steps in the supply chain such as payments • Low speed and flexibility • High paper usage is not environmentally friendly
Digital	• Feasible for logging steps in the supply chain centrally • Flexibility to implement various levels of complexity • Reliable, proven method	• No or low paper usage
Barcode	• Relatively easy to implement • Standard for most of the industry • Relatively cheap	• Requires applying labels with the barcodes • Limited data storage possible in a barcode
QR	• Allows for more information to be shared than with a barcode • Thus allows for more flexibility	• Requires more complicated system to operate efficiently
Direct RFID	• Allows for more capabilities compared to QR codes • Superior reliability in logging	• Pasting RFIDs on bouquets will diminish product quality for consumers • Poor operating speed due to finding RFID within bouquets • RFIDs are more expensive than labels • Required digital system is more complicated
Indirect RFID	• Allows for more capabilities compared to QR codes • Superior reliability in logging • Advantageous in agility when placed on the HD	• RFIDs are more expensive than labels • Required digital system is more complicated

On paper		Digital		Barcode		QR		Direct RFID		Indirect RFID	
SCOR Performance Attribute	Score	SCOR Performance Attribute	Score	SCOR Performance Attribute	Score	SCOR Performance Attribute	Score	SCOR Performance Attribute	Score	SCOR Performance Attribute	Score
Reliability	0	Reliability	+	Reliability	+	Reliability	+	Reliability	++	Reliability	++
Responsiveness	--	Responsiveness	0	Responsiveness	+	Responsiveness	+	Responsiveness	--	Responsiveness	+
Agility	--	Agility	+	Agility	+	Agility	++	Agility	-	Agility	+
Cost	0	Cost	+	Cost	0	Cost	-	Cost	--	Cost	0
Assets	--	Assets	0	Assets	0	Assets	0	Assets	--	Assets	0
Environmental	-	Environmental	++	Environmental	+	Environmental	+	Environmental	0	Environmental	0

Figure B.4: The SCOR performance score cards for the design options for log.

QC

Table B.5: Advantages and disadvantages of each design option for QC

Option	Advantages	Disadvantages
Manual	• Rigorous method providing certainty of high-quality results • Advantage in reliability • Industry standard • Flexible to changes in operations or product • Maximizes product quality by removing most outliers	• Time-expensive
Computer scan	• Maximizes product quality by removing most outliers	• Not commercially developed yet • Infeasible to develop at the limited scale of this supply chain in both complexity and costs
Sampling	• Advantage in costs • Superior in responsiveness due to reduced amount of checks needed • Very flexible where and when to sample	• Possible only in certain cases (e.g., after trust has been sufficiently developed between partners) • Higher chance of outliers passing QC and thus diminishing product quality

Manual		Computer scan		Sampling	
SCOR Performance Attribute	**Score**	**SCOR Performance Attribute**	**Score**	**SCOR Performance Attribute**	**Score**
Reliability	++	Reliability	--	Reliability	0
Responsiveness	0	Responsiveness	--	Responsiveness	++
Agility	+	Agility	--	Agility	++
Cost	0	Cost	--	Cost	+
Assets	++	Assets	++	Assets	-
Environmental	0	Environmental	0	Environmental	0

Figure B.5: The SCOR performance score cards for the design options for quality control.

Dispose waste (production)

Table B.6: Advantages and disadvantages of each design option for dispose waste (production)

Option	Advantages	Disadvantages
Recycling company	• Reliable option for management of waste streams • Provides advantage on environmental impact • Parity on responsiveness compared to other external waste disposal services	• Expensive due to contracting external partner
Composting	• Organic waste can be composted and reused, aligning with sustainability goals • Advantage on assets usage as waste can be reused in the system • More flexible due to constant availability of waste disposal method	• Takes longer to process waste • Takes more steps for company with waste
Incinerator	• Cheapest option to contract externally • Reliable option for management of waste streams • Parity on responsiveness compared to other external waste disposal services	• Does not align with goals of sustainability.

Recycling company	
SCOR Performance Attribute	Score
Reliability	+
Responsiveness	+
Agility	0
Cost	-
Assets	0
Environmental	+

Composting	
SCOR Performance Attribute	Score
Reliability	+
Responsiveness	-
Agility	+
Cost	0
Assets	+
Environmental	++

Incinerator	
SCOR Performance Attribute	Score
Reliability	+
Responsiveness	+
Agility	0
Cost	+
Assets	0
Environmental	--

Figure B.6: The SCOR performance score cards for the design options for disposing production waste.

Sell on spot market

Table B.7: Advantages and disadvantages of each design option for sell on spot market

Option	Advantages	Disadvantages
Auction	• Reliable option for selling overproduction • Accepts all types of flowers • Limits write-off compared to other options • Parity in responsiveness compared to industry standards	• Goes against goal of operating outside of auction system • Infeasible for smaller quantities
Wholesale trader	• Reliable contract possible with wholesaler to purchase all types of flowers • Provides flexibility due to accepting all overproduction • Little complexity involved	• Likely significant write-off compared to sales to other customers
Local florist(s)	• Will be able to sell at a higher margin • Product gets to consumers with fewer transport links, thus better for the environment	• Unpredictable and unlikely to create beneficial relationship • Not flexible due to dependency on day-to-day demand of florists
Outlet	• Sale directly to consumers can limit write-off compared to other options • Keeps sales in-house • Product gets to consumers with fewer transport links, thus better for the environment	• Limited scale when overproduction becomes too large • Sale may take longer compared to other options

Auction		Wholesale trader		Local florist(s)		Outlet	
SCOR Performance Attribute	Score	SCOR Performance Attribute	Score	SCOR Performance Attribute	Score	SCOR Performance Attribute	Score
Reliability	+	Reliability	+	Reliability	--	Reliability	0
Responsiveness	0	Responsiveness	+	Responsiveness	-	Responsiveness	-
Agility	++	Agility	++	Agility	-	Agility	0
Cost	0	Cost	-	Cost	+	Cost	+
Assets	+	Assets	+	Assets	0	Assets	++
Environmental	0	Environmental	0	Environmental	+	Environmental	+

Figure B.7: The SCOR performance score cards for the design options for selling on the spot market.

Produce bouquets

Table B.8: Advantages and disadvantages of each design option for produce bouquets

Option	Advantages	Disadvantages
Manual	• Low setup costs • Very reliable • Easier to make adjustments in production	• Not very fast
Automated	• Automated production of bouquets could be faster than manual	• Not proven on the commercial market yet • Requires extensive investments
Semi-automated	• Faster production • Reliable, proven technology	• Can be too expensive to invest in for limited volumes • Higher operating costs

Manual		Automated		Semi-automated	
SCOR Performance Attribute	Score	SCOR Performance Attribute	Score	SCOR Performance Attribute	Score
Reliability	++	Reliability	--	Reliability	+
Responsiveness	0	Responsiveness	++	Responsiveness	+
Agility	++	Agility	-	Agility	0
Cost	+	Cost	--	Cost	-
Assets	0	Assets	+	Assets	+
Environmental	+	Environmental	-	Environmental	0

Figure B.8: The SCOR performance score cards for the design options for producing bouquets.

Store

Table B.9: Advantages and disadvantages of each design option for store

Option	Advantages	Disadvantages
Ground floor	• Industry standard for storage • Flexible to reach goods	• -
Stacked	• More efficient land use	• Infeasible without expensive ramps and elevators • Takes longer to reach goods • Not used in the floriculture industry
Environmentally controlled	• Beneficial for shelf life and thus value of flowers and bouquets • Advantageous for reliability as product quality remains better for longer	• Not universal in the industry, for example auction also does not control the temperature • Energy usage makes it environmentally worse • Enclosed, isolated building makes it harder to reach quickly • Costs may outweigh benefits for shorter term stays
Internal	• Easier and higher availability of storage • Provides more flexible access to storage	• Requires initial capital investment and space • Requires operating ones own storage facilities
External	• Requires lower initial investment • Generally cheaper in the Netherlands due to high availability	• Complicates internal logistics slightly • Requires coordination with partner's property • Requires more transport links, impacting the environment

Ground floor		Stacked		Environmentally controlled		Internal		External	
SCOR Performance Attribute	Score	SCOR Performance Attribute	Score	SCOR Performance Attribute	Score	SCOR Performance Attribute	Score	SCOR Performance Attribute	Score
Reliability	++	Reliability	--	Reliability	+	Reliability	+	Reliability	+
Responsiveness	+	Responsiveness	--	Responsiveness	0	Responsiveness	+	Responsiveness	+
Agility	++	Agility	-	Agility	+	Agility	+	Agility	0
Cost	+	Cost	-	Cost	-	Cost	-	Cost	+
Assets	0	Assets	+	Assets	++	Assets	+	Assets	0
Environmental	0	Environmental	0	Environmental	-	Environmental	0	Environmental	-

Figure B.9: The SCOR performance score cards for the design options for store.

(Un-)load vehicle

Table B.10: Advantages and disadvantages of each design option for (un-)load vehicle

Option	Advantages	Disadvantages
Manual	• Very feasible due to limited weight of bouquets • Advantageous on reliability as extra care can be taken to maintain product quality • Cheap option and environmentally friendly	• Not very fast
Forklift	• -	• After loading with a forklift, unloading with a forklift is required and this requires a forklift at all destinations. That cannot be guaranteed and thus this method is not reliable • Expensive due to purchase and operating costs of forklifts
Electric hand-drawn	• Advantageous in responsiveness for traversing longer distances faster with heavy loads • Reliable transport up to the vehicle itself • Flexible to retrieve larger loads from longer distances simultaneously	• Necessary only for longer distances with heavy loads • More expensive to operate compared to manual
Roll on-roll off	• Offers reliable loading of the entire vehicle in one go	• Infeasible due to fragility of contents and vending point • Requires specialized equipment or extensive servicing • Limits available locations for vending points due to space requirements • Would require a larger pool of vending points to allow for the replacement vending point • Larger vehicle necessary thus environmentally less friendly

Manual		Forklift truck		Electric hand-drawn		Roll on-roll off	
SCOR Performance Attribute	**Score**	**SCOR Performance Attribute**	**Score**	**SCOR Performance Attribute**	**Score**	**SCOR Performance Attribute**	**Score**
Reliability	++	Reliability	-	Reliability	+	Reliability	++
Responsiveness	0	Responsiveness	-	Responsiveness	++	Responsiveness	-
Agility	+	Agility	0	Agility	++	Agility	--
Cost	++	Cost	--	Cost	0	Cost	--
Assets	0	Assets	--	Assets	+	Assets	+
Environmental	+	Environmental	-	Environmental	0	Environmental	--

Figure B.10: The SCOR performance score cards for the design options for (un-)loading vehicles.

Move vehicle

Table B.11: Advantages and disadvantages of each design option for move vehicle

Option	Advantages	Disadvantages
Truck	• Reliable transport option	• Infeasible due to scale difference between required cargo and size of truck • Complicates nearby parking, limiting flexibility • Higher operating costs • Larger vehicle has a higher environmental impact per distance driven
Van	• Reliable proven transport option • Advantage in flexibility and agility • Good on costs and investment	• -
Cargo bike	• Environmentally friendly	• Range and capacity restrictions limits usefulness in the wider supply chain
Car plus trailer	• Method commonly used by florists • Able to deliver flowers on a similar speed compared to other vehicles	• Not very flexible on its own due to limited size of trailer • For an isolated supply chain would require investment in a vehicle with a tow bar as well
Electric	• Superior in environmental sense. • Similar flexibility compared to fossil fuel vans • Lower operating costs compared with fossil fuel vans	• Some range limitations but not much when limited to The Netherlands • Longer turnaround times due to charging • Higher investment costs compared with fossil fuel vans
Fossil fuels	• Not that expensive compared to electric vehicles • Lower turnaround times due to easier refueling	• Not environmentally sustainable • Higher operating costs compared to electric driving

Truck		Van		Cargo bike		Car plus trailer		Electric		Fossil fuels	
SCOR Performance Attribute	Score	SCOR Performance Attribute	Score	SCOR Performance Attribute	Score	SCOR Performance Attribute	Score	SCOR Performance Attribute	Score	SCOR Performance Attribute	Score
Reliability	+	Reliability	++	Reliability	0	Reliability	+	Reliability	+	Reliability	++
Responsiveness	0	Responsiveness	+	Responsiveness	+	Responsiveness	+	Responsiveness	0	Responsiveness	++
Agility	--	Agility	++	Agility	--	Agility	0	Agility	+	Agility	+
Cost	-	Cost	+	Cost	+	Cost	0	Cost	0	Cost	--
Assets	0	Assets	+	Assets	+	Assets	0	Assets	-	Assets	+
Environmental	--	Environmental	0	Environmental	++	Environmental	0	Environmental	++	Environmental	--

Figure B.11: The SCOR performance score cards for the design options for move vehicle.

Receive vehicle

Table B.12: Advantages and disadvantages of each design option for receive vehicle

Option	Advantages	Disadvantages
Park nearby	• No investment required as it utilizes existing infrastructure • Parking is available at many locations	• Requires investigation of parking availability near vending points
Unloading facilities	• Parking availability is guaranteed	• Inclusion would seriously limit possibilities for vending locations • (Development) costs of unloading facilities high

Park nearby		Unloading facilities	
SCOR Performance Attribute	Score	SCOR Performance Attribute	Score
Reliability	0	Reliability	+
Responsiveness	+	Responsiveness	+
Agility	+	Agility	--
Cost	+	Cost	--
Assets	0	Assets	-
Environmental	0	Environmental	-

Figure B.12: The SCOR performance score cards for the design options for receive vehicle.

Service vending point

Table B.13: Advantages and disadvantages of each design option for service vending point

Option	Advantages	Disadvantages
Cleaning	• Improves perceived product quality and thus reliable for customers • Flexible operation to perform	• -
Remove old flowers	• Improves appearance of vending point and thus reliable for customers • Quite fast to do when guided correctly • Only removes low value product	• -
Remove all flowers	• Improves speed and responsiveness of servicing as no guidance is required • Keeps reliability above average for consumers	• No flexibility to adapt to actual conditions • Also removes products that could have been sold, which is also wasteful
Resupply environmental control materials	• A flexible operation to perform when at the vending point	• Inclusion would incur significant requirements on both vending points and vehicle • Expensive to include all these materials • Takes some time to perform correctly

Cleaning		Remove old flowers		Remove all flowers		Resupply env. control material	
SCOR Performance Attribute	Score	SCOR Performance Attribute	Score	SCOR Performance Attribute	Score	SCOR Performance Attribute	Score
Reliability	+	Reliability	+	Reliability	+	Reliability	0
Responsiveness	0	Responsiveness	+	Responsiveness	++	Responsiveness	-
Agility	+	Agility	+	Agility	--	Agility	+
Cost	0	Cost	+	Cost	0	Cost	--
Assets	0	Assets	0	Assets	--	Assets	--
Environmental	0	Environmental	0	Environmental	-	Environmental	--

Figure B.13: The SCOR performance score cards for the design options for service vending point.

Stocking

Table B.14: Advantages and disadvantages of each design option for stocking

Option	Advantages	Disadvantages
Manual	• Allows for more flexibility • Quite fast to do • Reliable option to perform	• -
Roll on-roll off	• Very fast restocking due to all actions performed at once	• High investment in roll on-roll off infrastructure required • Lower reliability due to space constraints for performing the required operations
Swap out of HDs	• Faster restocking than manual swapping of bouquets • Advantageous in cost • Maintains parity in reliability	• Requires the HDs to match the earlier supply chain as well as the vending point • Custom HDs would limit the flexibility with the product

Manual		Roll on-roll off		Swap out of HDs	
SCOR Performance Attribute	Score	SCOR Performance Attribute	Score	SCOR Performance Attribute	Score
Reliability	+	Reliability	0	Reliability	+
Responsiveness	+	Responsiveness	++	Responsiveness	++
Agility	+	Agility	--	Agility	0
Cost	0	Cost	--	Cost	+
Assets	0	Assets	--	Assets	-
Environmental	0	Environmental	-	Environmental	0

Figure B.14: The SCOR performance score cards for the design options for stocking.

Dispose waste (vending points)

Table B.15: Advantages and disadvantages of each design option for dispose waste (vending points)

Option	Advantages	Disadvantages
Local	• Fast to dispose the waste nearby	• Not all locations have facilities available to dispose waste • Severely limits options for vending point placement • No guaranteed environmentally friendly processing of waste
Contracted separately	• Reliable method to collect the waste • No need to dedicate part of vehicle to waste collection	• Requires dedicated location for temporarily storing waste at each vending point • Requires contracting separate collection by partner or different vehicle which is expensive
Take back with you	• Reliable option as vehicle is always available when servicing • Advantage in cost as no separate trip to the vending points is required • Flexible in availability • Possible to guarantee adequate environmentally friendly disposal of waste	• Part of vehicle has to be dedicated for storing waste

Local		Contracted separately		Take back with you	
SCOR Performance Attribute	Score	SCOR Performance Attribute	Score	SCOR Performance Attribute	Score
Reliability	--	Reliability	+	Reliability	++
Responsiveness	+	Responsiveness	0	Responsiveness	+
Agility	--	Agility	-	Agility	++
Cost	0	Cost	--	Cost	+
Assets	+	Assets	+	Assets	-
Environmental	-	Environmental	0	Environmental	+

Figure B.15: The SCOR performance score cards for the design options for disposing vending point waste.

Sell to consumers

Table B.16: Advantages and disadvantages of each design option for sell to consumers

Option	Advantages	Disadvantages
At location	• Proven concept at the core of the company • Fastest usage of supply chain due to lower interactions and tracing required • No extra costs necessary	• No flexible purchases in advance possible
Online in advance based on stock	• Improves service quality for consumers • Not overly expensive to include • Offers more flexibility for consumers	• Requires central coordination system to present stock-in-store online • Longer purchase time as consumers need to look up availability ahead of time
Online made-to-order	• Allows for optimal service quality for consumers • Advantageous usage of company assets to create maximum value • Offers most flexibility for consumers	• Requires significantly advanced central coordination system • Introduces significant complexity in other steps of the supply chain • Special delivery may delay purchase for consumer significantly

At location		Online based on stock		Online made-to-order	
SCOR Performance Attribute	Score	SCOR Performance Attribute	Score	SCOR Performance Attribute	Score
Reliability	+	Reliability	+	Reliability	++
Responsiveness	+	Responsiveness	0	Responsiveness	-
Agility	-	Agility	0	Agility	+
Cost	++	Cost	+	Cost	--
Assets	+	Assets	+	Assets	++
Environmental	0	Environmental	0	Environmental	0

Figure B.16: The SCOR performance score cards for the design options for sell to consumers.

Provide proof of delivery

Table B.17: Advantages and disadvantages of each design option for provide proof of delivery

Option	Advantages	Disadvantages
Printed receipt	• Reliable, proven method	• Takes a while to print • Can only be provided on location directly after purchase • Requires paper and printer
Digital receipt	• Instantly delivers receipt to consumer • Requires little further infrastructure • Advantageous in costs • No paper used in the process	• -
Register in consumer account	• Easier to find later for consumers compared to digital receipt • Would require synchronizing with consumer data, taking longer to deliver receipt	• Only feasible if account system is in place in the central coordination system • Requires investment into such a system

Printed receipt		Digital receipt		Register in consumer account	
SCOR Performance Attribute	Score	SCOR Performance Attribute	Score	SCOR Performance Attribute	Score
Reliability	++	Reliability	+	Reliability	++
Responsiveness	-	Responsiveness	++	Responsiveness	+
Agility	--	Agility	+	Agility	+
Cost	-	Cost	++	Cost	+
Assets	-	Assets	0	Assets	-
Environmental	--	Environmental	+	Environmental	+

Figure B.17: The SCOR performance score cards for the design options for proof of delivery.

C

Detailed design options for the four design alternatives

Tables C.1 up to C.4 describe the options chosen in the morphological charts and their reasoning.

Table C.1: A table describing the options chosen from the morphological chart for the design of alternative 1 and their reasoning.

Function description	Function number(s)	Chosen option(s)	Reasoning
Internal receival	1.2	Roll containers	Internal production will be handled as similar as possible to external deliveries and thus only accepted using the industry-standard containers and roll containers.
External receival	1.3	Roll containers	Using roll containers is the industry standard for transport and thus most likely how the externally sourced flowers will arrive.
Prepare internal	1.4	As-is	Internal deliveries of flowers will be standardised already and can thus be forwarded without much repackaging.
Prepare external	1.5	As-is	External deliveries should arrive on roll containers in standardised containers, thus no repackaging should be necessary.
Move	1.6, 1.7, 1.10, 2.1, 2.6, 2.7, 3.2, 4.1, 4.4, 5.2	Manual Electric hand-drawn	Movement of flowers within the facilities will be centered around the standardised handling devices on roll containers. For small numbers and short distances, these can be moved by hand. Electric trolleys for transporting roll containers can assist in other cases.
Log internal receivals	1.8	Digital	Internal flower tracing starts after they have been repacked into their containers. No further tracking per flower or bunch of flowers is added to the system to reduce complexity.
Log external receivals	1.9	Digital	External deliveries should also be tracked digitally, and no further tracking is added in this design.
Perform QC	2.2, 3.5	Manual	Quality control of the both types of deliveries can be checked at multiple stages as there is no repackaging involved. QC for flowers and bouquets is still most optimal to perform manually.
Log QC	2.3, 3.6	Digital	The quality control results can be logged digitally looking up the product that has been inspected in this system.
Dispose waste (production)	2.5, 3.7	Recycle company	The flowers that will not be used due to failing QC will be given to a recycling company specialized in organic waste to process.
Sell on spot market	2.8	Wholesale trader	The overproduction in the system can most easily be sold off to a wholesale trader that has a blanket deal with the company to purchase this stock at a negotiated write-off.
Collect packaging material	3.3	Pallets	Packaging material shipped in large quantities is often palletize for easier transport. Thus, limited pallet handling infrastructure must be available.
Produce bouquets	3.4	Semi-automated	In this design option, a separate company specialized in bouqueting will be contracted to create the bouquets using their scale benifits. This allows for the inclusion of a semi-automated production system in the design, but limits the control on the bouquets.
Prepare bouquets for storage	3.8	As-is	The bouquets will be retrieved from the bouqueting partner using standardised containers, which can be used for storage as well.
Log storage	4.2	Digital	Storage operations can be logged digitally indicating what is stored where in the storage location.
Store	4.3	Internal External Ground-floor	In this design, storage is more comparable to operations at the auction: here, flowers are kept for as little time as possible without environmental control in operations comparable to cross-docking: receiving, limited processing and then transporting again. Limited space for such operations must be available at the company's own site, and such space is also available externally in the existing floriculture supply chain.
(Un-)load vehicle	5.3, 6.3	Manual	Due to the fragility and relatively low weight of bouquets, they are best loaded by hand into the vehicle using the standardised containers they are stored in.
Move vehicle	5.4	Fossil fuel van	The replenishment of self-owned vending points at different locations is best done using a milk run methodology, bringing the required stock to multiple locations in a row. For approachability of all locations, a van is most suited. This van can be customized to hold the standardised containers for the bouquets, from which the bouquets can be placed in the vending points. As more trips per day are expected to be necessary in this design, fossil fuel-powered vans are more suited for this solution due to charge times of electric vehicles.
Receive vehicle	6.2	Park nearby	A van is able to reach most locations relatively nearby, and the remaining distance can be covered by foot together with the goods. A type of cart will be useful here to include when the distance becomes larger than a few meters.
Service vending point	6.4	Cleaning Remove all flowers	The vending point is cleaned and all unsold stock will be removed as well to simplify the planning of restocking operations. In this way, every restock is for the entire capacity of the vending point and thus fewer visits have to be made, as well as simplifying the transport operation by making the transported load fixed ahead of time.
Stocking	6.5	Manual	The bouquets are taken from the standardised containers and placed in fixed containers in the vending point.
Dispose waste at vending point	6.6, 6.7	Take back with you	The waste from the vending point servicing and restocking must be able to be transported back with the custom vehicle to prevent limitations to vending point locations due to issues with waste handling.
Sell to consumer	8.1	At location	As the traceability of products in this system is limited, no online purchase options will be provided to consumers.
Provide proof of delivery	8.2	Digital receipt	Customers will be given the option to receive a digital receipt to limit the paper usage in the chain. No further options will be available in this design.
Log sales	8.3	Digital	The sale of a product will be logged digitally in the sales system.

Table C.2: A table describing the options chosen from the morphological chart for the design of alternative 2 and their reasoning.

Function description	Function number(s)	Chosen option(s)	Reasoning
Internal receival	1.2	Conveyor system Roll containers	Harvested flowers from the internal production location will be placed on a system of conveyors that will guide them out of the greenhouses for further processing. Some flowers types may be more suited to be transported on roll containers.
External receival	1.3	Roll containers	Using roll containers is the industry standard for transport and thus most likely how the externally sourced flowers will arrive.
Prepare internal	1.4	Repack to standardised container	As the flowers from the internal production location will arrive separated and in most cases on conveyor belts, they should be repacked into standardised containers which can be placed on roll containers for easier future processing.
Prepare external	1.5	As-is	External deliveries should arrive on roll containers in standardised containers, thus no repackaging should be necessary.
Move	1.6, 1.7, 1.10, 2.1, 2.6, 2.7, 3.2, 4.1, 4.4, 5.2	Manual Electric hand-drawn	Movement of flowers within the facilities will be centered around the standardised handling devices on roll containers. For small numbers and short distances, these can be moved by hand. Electric trolleys for transporting roll containers can assist in other cases.
Log internal receivals	1.8	Digital Barcode	Internal flower tracing starts after they have been repacked into their containers. Their reception will then be tracked digitally as well as physically using a barcode label, to keep a similar system to the industry standard.
Log external receivals	1.9	Digital Barcode	External deliveries should also be tracked digitally, and they arrive with a standardized barcode from earlier transport that can be reused for future tasks.
Perform QC	2.2, 3.5	Manual	Quality control of the internal flower deliveries should be performed in conjunction with the repackaging for efficiency, whereas external deliveries can be checked at more stages. QC for flowers and bouquets is still most optimal to perform manually.
Log QC	2.3, 3.6	Digital QR	The quality control results can be logged digitally using the barcode system added in the earlier phase of the chain. The bouquets can be labeled here as well to update their new condition with a QR code, which can be linked digitally to earlier barcodes.
Dispose waste (production)	2.5, 3.7	Composting	Any flowers disposed during QC that fail to meet the criteria, will constitute a mass of organic waste that can be converted into new useful products like compost. As a part of the brand that Priva wants to build, it would fit if this waste is composted on-site to be used for future production.
Sell on spot market	2.8	Outlet Wholesale trader	In the case of the centralized and unified system, a separate outlet vending point for cheaper overproduction can be possible. For the remainder of the overproduction, a deal with a wholesale trader is envisioned who will purchase the stock. This is chosen to keep involvement with the auction system minimal.
Collect packaging material	3.3	Pallets	Packaging material shipped in large quantities is often palletized for easier transport. Thus, limited pallet handling infrastructure must be available.
Produce bouquets	3.4	Manual	In this design option, production will be in-house and thus limited to the quantity required in the own chain. It can be expected that this quantity is too low (at least initially) to justify the expense of a (semi-)automated system.
Prepare bouquets for storage	3.8	Repack to custom containers	Before storage, the bouquets can already be repacked into custom containers that are easier to handle in the later (re-)stocking phase to prevent double handling.
Log storage	4.2	Digital	Storage operations can be logged using the barcode system that was added to the flowers and bouquets.
Store	4.3	Internal Ground-floor Environmentally controlled	As operations are centered around the internal production and handling location, it would be wise to include a storage facility in the development of these plans to limit the distances involved. Such a custom system is most commonly single floor and has environmental control with separate cells for different conditions.
(Un-)load vehicle	5.3, 6.3	Manual	Due to the fragility and relatively low weight of bouquets, they are best loaded by hand into the vehicle using the custom container that can also be used for (re-)stocking.
Move vehicle	5.4	Electric van	The replenishment of self-owned vending points at different locations is best done using a milk run methodology, bringing the required stock to multiple locations in a row. For approachability of all locations, a van is most suited. This van can be customized to hold the custom containers for the bouquets that can be placed in the vending points. To align with the company profile, electric vehicles are selected.
Receive vehicle	6.2	Park nearby	A van is able to reach most locations relatively nearby, and the remaining distance can be covered by foot together with the goods. A type of cart will be useful here to include when the distance becomes larger than a few meters.
Service vending point	6.4	Cleaning Remove old flowers	The shelves that have been used as well as flowers deemed too old for sale will be removed in this design, such that the appearance of the vending points remains good.
Stocking	6.5	Swap out of containers	As the bouquets come in custom containers, these can be easily swapped in and out of the vending points.
Dispose waste at vending point	6.6, 6.7	Take back with you	The waste from the vending point servicing and restocking must be able to be transported back with the custom vehicle to prevent limitations to vending point locations due to issues with waste handling.
Sell to consumer	8.1	At location Online based on stock Online made-to-order	Using the traceability of the products in the system and the digital availability of this data, more advanced purchases can be facilitated for consumers other than directly from the vending point.
Provide proof of delivery	8.2	Digital receipt Register in account	Customers will be given the option to receive a digital receipt to limit the paper usage in the chain. Returning customers with an account (also used for online purchases) can track their purchases in their account.
Log sales	8.3	Digital QR	The sale of a product will be logged digitally in the central coordination system, and the consumer can find information about their purchase using the QR code that was added to the bouquets during production.

Table C.3: A table describing the options chosen from the morphological chart for the design of alternative 3 and their reasoning.

Function description	Function number(s)	Chosen option(s)	Reasoning
Internal receival	1.2	Conveyor system Roll containers	Harvested flowers from the internal production location will be placed on a system of conveyors that will guide them out of the greenhouses for further processing. Some flowers types may be more suited to be transported on roll containers.
External receival	1.3	Roll containers	Using roll containers is the industry standard for transport and thus most likely how the externally sourced flowers will arrive.
Prepare internal	1.4	Repack to standardised container	As the flowers from the internal production location will arrive separated and in most cases on conveyor belts, they should be repacked into standardised containers which can be placed on roll containers for easier future processing.
Prepare external	1.5	As-is	External deliveries should arrive on roll containers in standardised containers, thus no repackaging should be necessary.
Move	1.6, 1.7, 1.10, 2.1, 2.6, 2.7, 3.2, 4.1, 4.4, 5.2	Manual Electric hand-drawn	Movement of flowers within the facilities will be centered around the standardised handling devices on roll containers. For small numbers and short distances, these can be moved by hand. Electric trolleys for transporting roll containers can assist in other cases.
Log internal receivals	1.8	Digital Barcode	Internal flower tracing starts after they have been repacked into their containers. Their reception will then be tracked digitally as well as physically using a barcode label, to keep a similar system to the industry standard.
Log external receivals	1.9	Digital Barcode	External deliveries should also be tracked digitally, and they arrive with a standardized barcode from earlier transport that can be reused for future tasks.
Perform QC	2.2, 3.5	Manual	Quality control of the internal flower deliveries should be performed in conjunction with the repackaging for efficiency, whereas external deliveries can be checked at more stages. QC for flowers and bouquets is still most optimal to perform manually.
Log QC	2.3, 3.6	Digital QR	The quality control results can be logged digitally using the barcode system added in the earlier phase of the chain. The bouquets can be labeled here as well to update their new condition with a QR code, which can be linked digitally to earlier barcodes.
Dispose waste (production)	2.5, 3.7	Recycling company	The flowers that will not be used due to failing QC will be given to a recycling company specialized in organic waste to process.
Sell on spot market	2.8	Auction	The overproduction of flowers can be transported to the auction using an industry partner and then sold using this established system. There is little effort involved here as these products have already passed QC at this point and are located on standardised containers.
Collect packaging material	3.3	Pallets	Packaging material shipped in large quantities is often palletized for easier transport. Thus, limited pallet handling infrastructure must be available.
Produce bouquets	3.4	Semi-automated	In this design option, a separate company specialized in bouqueting will be contracted to create the bouquets using their scale benefits. This allows for the inclusion of a semi-automated production system in the design, but limits the control on the bouquets.
Prepare bouquets for storage	3.8	As-is	The bouquets will be retrieved from the bouqueting partner using standardised containers, which can be used for storage as well.
Log storage	4.2	Digital	Storage operations can be logged using the barcode system that was added to the flowers and bouquets.
Store	4.3	Internal External Ground-floor	In this design, storage is more comparable to operations at the auction: here, flowers are kept for as little time as possible without environmental control in operations comparable to cross-docking: receiving, limited processing and then transporting again. Limited space for such operations must be available at the company's own site, and such space is also available externally in the existing floriculture supply chain.
(Un-)load vehicle	5.3, 6.3	Manual	Due to the fragility and relatively low weight of bouquets, they are best loaded by hand into the vehicle into a custom container that can also be used for (re-)stocking.
Move vehicle	5.4	Van (plus trailer) Electric Fossil fuels	Florists regularly transport fresh quantities of flowers from wholesalers or auction partners using their privately owned vans (some with trailers). These vehicles can be electric, but most are using fossil fuels. Replenishment can be performed by a network of florists that cooperate with the company and they will be recompensated for this effort. Product transport in this design thus "hitchhikes" along their existing trips.
Receive vehicle	6.2	Park nearby	A van is able to reach most locations relatively nearby, and the remaining distance can be covered by foot together with the goods. A type of cart will be useful here to include when the distance becomes larger than a few meters.
Service vending point	6.4	Cleaning Remove old flowers	The shelves that have been used as well as flowers deemed too old for sale will be removed in this design, such that the appearance of the vending points remains good.
Stocking	6.5	Swap out of containers	As the bouquets come in custom containers, these can be easily swapped in and out of the vending points.
Dispose waste at vending point	6.6, 6.7	Contracted separately	The waste from the vending point servicing and restocking must be able to be transported back by the restocker to prevent limitations to vending point locations due to issues with waste handling. As this will be a local florist partner, they can be contracted to process this waste using their method of preference for their own store(s).
Sell to consumer	8.1	At location Online based on stock	Using the traceability of the products in the system and the digital availability of this data, more advanced purchases can be facilitated for consumers other than directly from the vending point. No made-to-order will be provided due to the usage of an external bouqueting company as this would introduce too many complexities in the system.
Provide proof of delivery	8.2	Digital receipt Register in account	Customers will be given the option to receive a digital receipt to limit the paper usage in the chain. Returning customers with an account (also used for online purchases) can track their purchases in their account.
Log sales	8.3	Digital QR	The sale of a product will be logged digitally in the central coordination system, and the consumer can find information about their purchase using the QR code that was added to the bouquets during production.

Table C.4: A table describing the options chosen from the morphological chart for the design of alternative 4 and their reasoning.

Function description	Function number(s)	Chosen option(s)	Reasoning
Internal receival	1.2	Roll containers	To align with the most common delivery method of flowers, roll containers will be used to transport the flowers internally. This system is flexible for adaptation later on, and can be augmented by a conveyor system at a later stage.
External receival	1.3	Roll containers	Using roll containers is the industry standard for transport and thus most likely how the externally sourced flowers will arrive.
Prepare internal	1.4	Repack to standardised container	As the flowers from the internal production location will arrive separated and in most cases on conveyor belts, they should be repacked into standardised containers which can be placed on roll containers for easier future processing.
Prepare external	1.5	As-is	External deliveries should arrive on roll containers in standardised containers, thus no repackaging should be necessary.
Move	1.6, 1.7, 1.10, 2.1, 2.6, 2.7, 3.2, 4.1, 4.4, 5.2	Manual Electric hand-drawn	Movement of flowers within the facilities will be centered around the standardised handling devices on roll containers. For small numbers and short distances, these can be moved by hand. Electric trolleys for transporting roll containers can assist in other cases.
Log internal receivals	1.8	Digital Barcode	Internal flower tracing starts after they have been repacked into their containers. Their reception will then be tracked digitally as well as physically using a barcode label on the containers, to keep a similar system to the industry standard.
Log external receivals	1.9	Digital Barcode	External deliveries should also be tracked digitally, and they arrive with a standardized barcode from earlier transport that can be reused for future tasks.
Perform QC	2.2, 3.5	Manual	Quality control of the internal flower deliveries should be performed in conjunction with the repackaging for efficiency, whereas external deliveries can be checked at more stages. QC for flowers and bouquets is still most optimal to perform manually.
Log QC	2.3, 3.6	Digital	The quality control results can be logged digitally using the barcode system added in the earlier phase of the chain. In this design, no visible traceability will be present on the bouquets for customers as that can be added in a later stage.
Dispose waste (production)	2.5, 3.7	Recycle company	Whilst composting and re-using organic waste can still be a design goal in the end, to ease the starting of operations it will be better to sign a contract with a recycle company to process the waste of this step.
Sell on spot market	2.8	Auction Wholesale trader	In this supply chain design alternative, it is easiest to divert focus from offsetting overproduction for now. As the marginal return on this flow of goods is low, it is best to go for a simple approach to sell off remaining flowers via the auction or a deal with a wholesale trader.
Collect packaging material	3.3	Pallets	Packaging material shipped in large quantities is often palletized for easier transport. Thus, limited pallet handling infrastructure must be available.
Produce bouquets	3.4	Manual	In this design option, production will be in-house and thus limited to the quantity required in the own chain. At this stage of growth in the system, the inclusion of a semi-automated system in the design cannot be justified due to the lower volumes.
Prepare bouquets for storage	3.8	Repack to standardised container	Before storage, the bouquets will be placed in the standardised containers that the whole chain is built upon, to allow for maximum flexibility.
Log storage	4.2	Digital	Storage operations can be logged using the barcode system that was added to the containers.
Store	4.3	Internal Ground-floor Environmentally controlled	As operations are centered around the internal production and handling location, it would be wise to include a storage facility in the development of these plans to limit the distances involved. Such a custom system is most commonly single floor and has environmental control with separate cells for different conditions.
(Un-)load vehicle	5.3, 6.3	Manual	Due to the fragility and relatively low weight of bouquets, they are best loaded by hand into the vehicle using the custom container that can also be used for (re-)stocking.
Move vehicle	5.4	Electric van	The replenishment of self-owned vending points at different locations is best done using a milk run methodology, bringing the required stock to multiple locations in a row. For approachability of all locations, a van is most suited. This van can be customized to hold standardised containers for the bouquets, out of which they can be picked and placed in the vending points. To align with the company profile, electric vehicles are selected.
Receive vehicle	6.2	Park nearby	A van is able to reach most locations relatively nearby, and the remaining distance can be covered by foot together with the goods. A type of cart will be useful here to include when the distance becomes larger than a few meters.
Service vending point	6.4	Cleaning Remove old flowers	The shelves that have been used as well as flowers deemed too old for sale will be removed in this design, such that the appearance of the vending points remains good.
Stocking	6.5	Manual	As the bouquets come in standardised containers, they have to be placed in a vase system that is already present in the vending points. The standardised containers will then be returned to the company hub.
Dispose waste at vending point	6.6, 6.7	Take back with you	The waste from the vending point servicing and restocking must be able to be transported back with the custom vehicle to prevent limitations to vending point locations due to issues with waste handling.
Sell to consumer	8.1	At location	In the phase that this design alternative aims at, traceability for customers is not available yet. Thus, only sales on location are possible for now, with room for growth when a tracing system is added to the produced bouquets.
Provide proof of delivery	8.2	Digital receipt	Customers will be given the option to receive a digital receipt to limit the paper usage in the chain. No further options will be available initially, as no customer accounts exist in this design (yet).
Log sales	8.3	Digital	The sale of a product will be logged digitally in the central coordination system.

D
The SCOR model

In this thesis project, the SCOR mapping method is used to represent the physical designs in chapter 5. Here, a legend for the SCOR nomenclature is given in table D.1 (ASCM, 2022).

Table D.1: A table of the level 2 SCOR nomenclature and processes

SCOR nomenclature	SCOR process
Plan	
P1	Plan Supply Chain
P2	Plan Order
P3	Plan Source
P4	Plan Transform
P5	Plan Fulfill
P6	Plan Return
Order	
O1	Order B2C
O2	Order B2B
O3	Order Intra-Company
Source	
S1	Strategic Source
S2	Direct Procedure
S3	Indirect Procedure
S4	Source Return
Fulfill	
F1	Fulfill B2C
F2	Fulfill B2B
F3	Fulfill Intra-company
Transform	
T1	Transform Product
T2	Transform Service
T3	Transform Maintenance, Repair, and Overhaul (MRO)
Return	
R1	Return Product
R2	Return Service
R3	Return MRO

E
Enterprise Architecture Models

In this appendix, the enterprise architecture models that were created for the digital systems design are found. Figure E.1 is a legend for the components and relations used in the representation of these models.

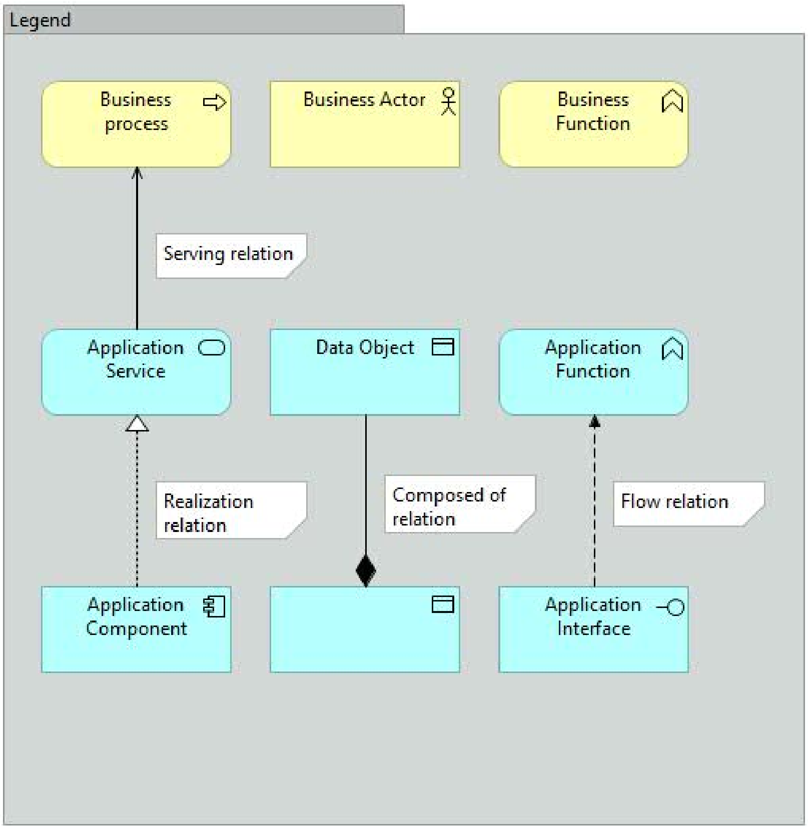

Figure E.1: A legend representing the components and relationships between components that are used in the enterprise architecture models based on the Archi standard (The Open Group Standard, 2022).

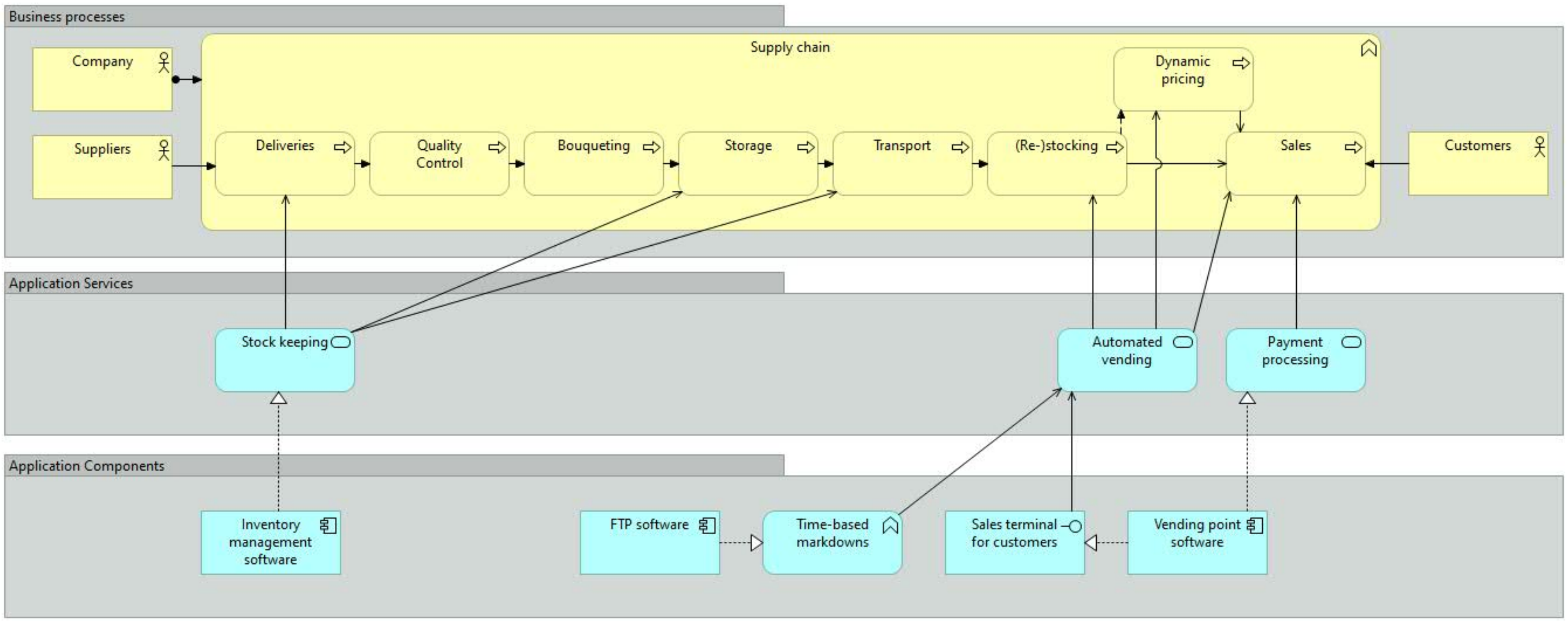

Figure E.2: An Enterprise Architecture model of the digital systems design for design alternative 1: keep it short & simple.

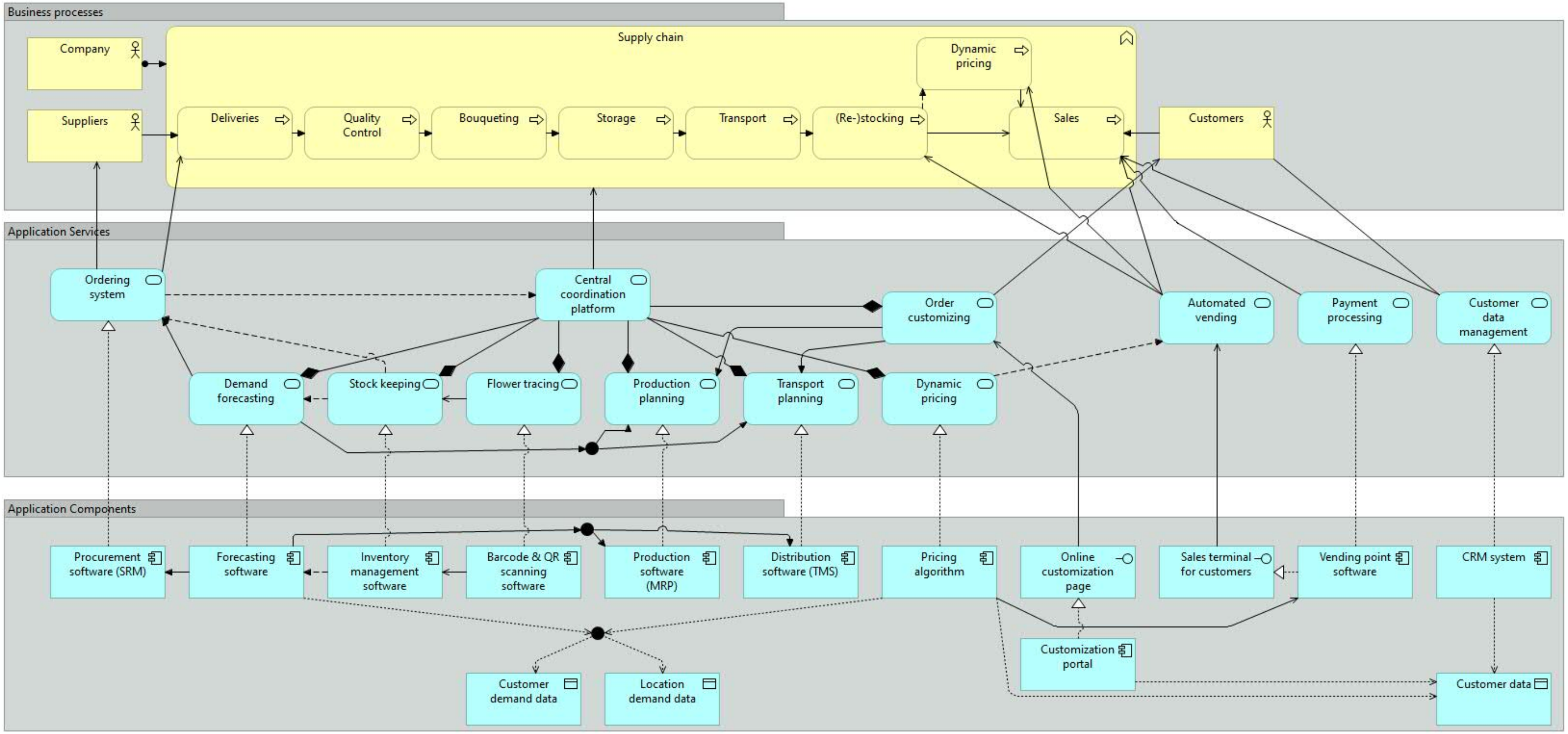

Figure E.3: An Enterprise Architecture model of the digital systems design for design alternative 2: centralised and unified operations.

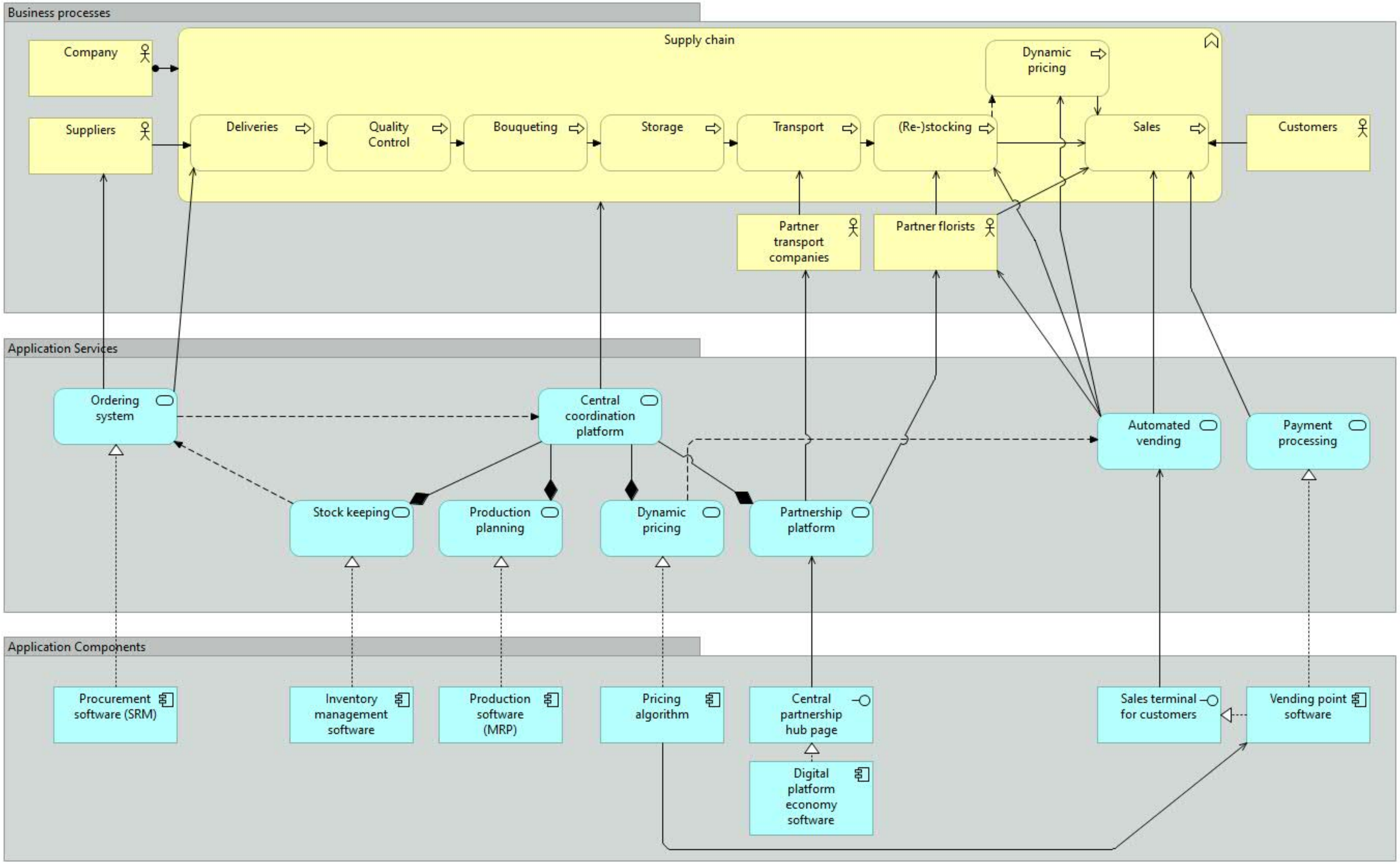

Figure E.4: An Enterprise Architecture model of the digital systems design for design alternative 3A: leveraging the existing chain (make-to-stock).

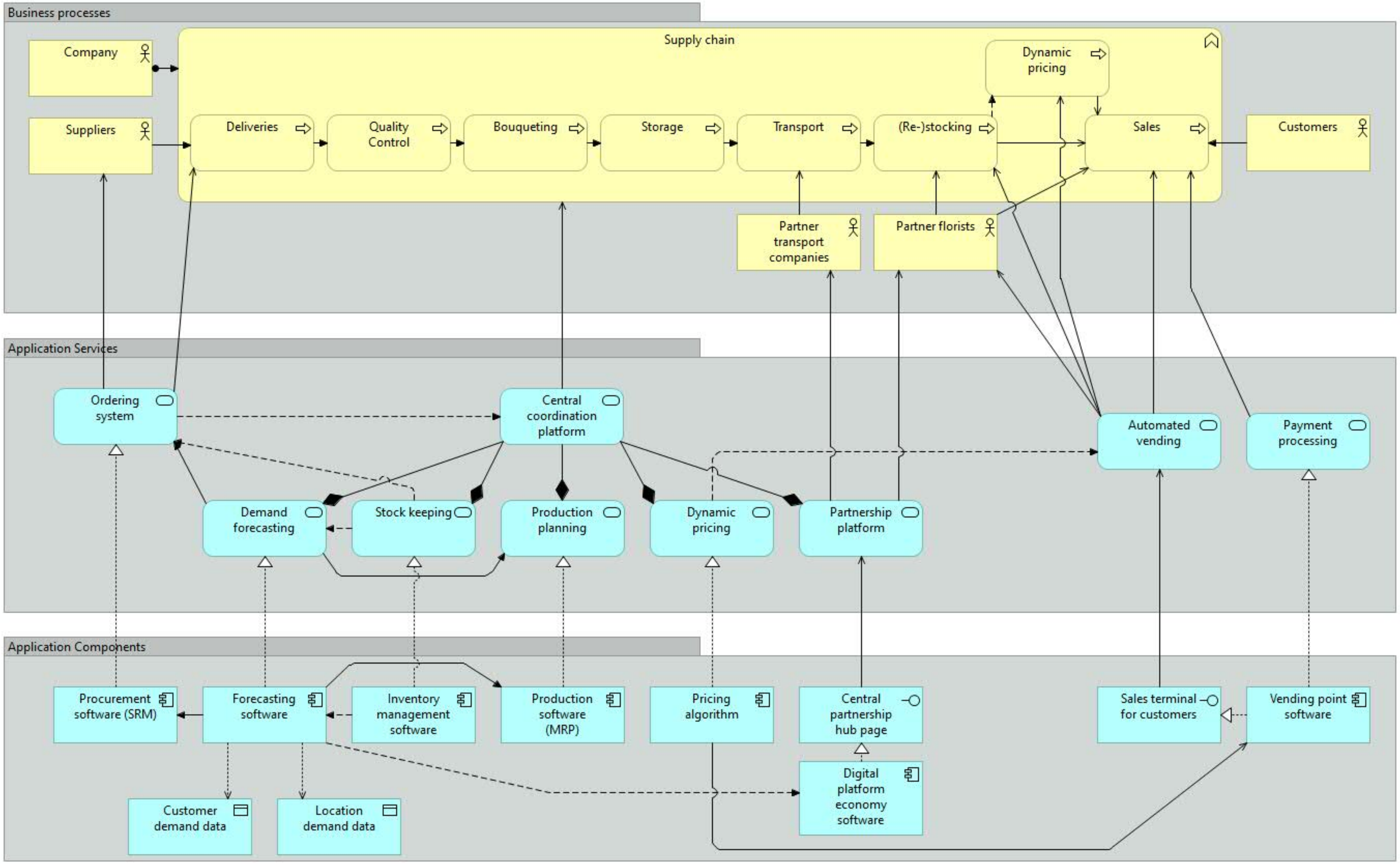

Figure E.5: An Enterprise Architecture model of the digital systems design for design alternative 3B: leveraging the existing chain (make-to-order).

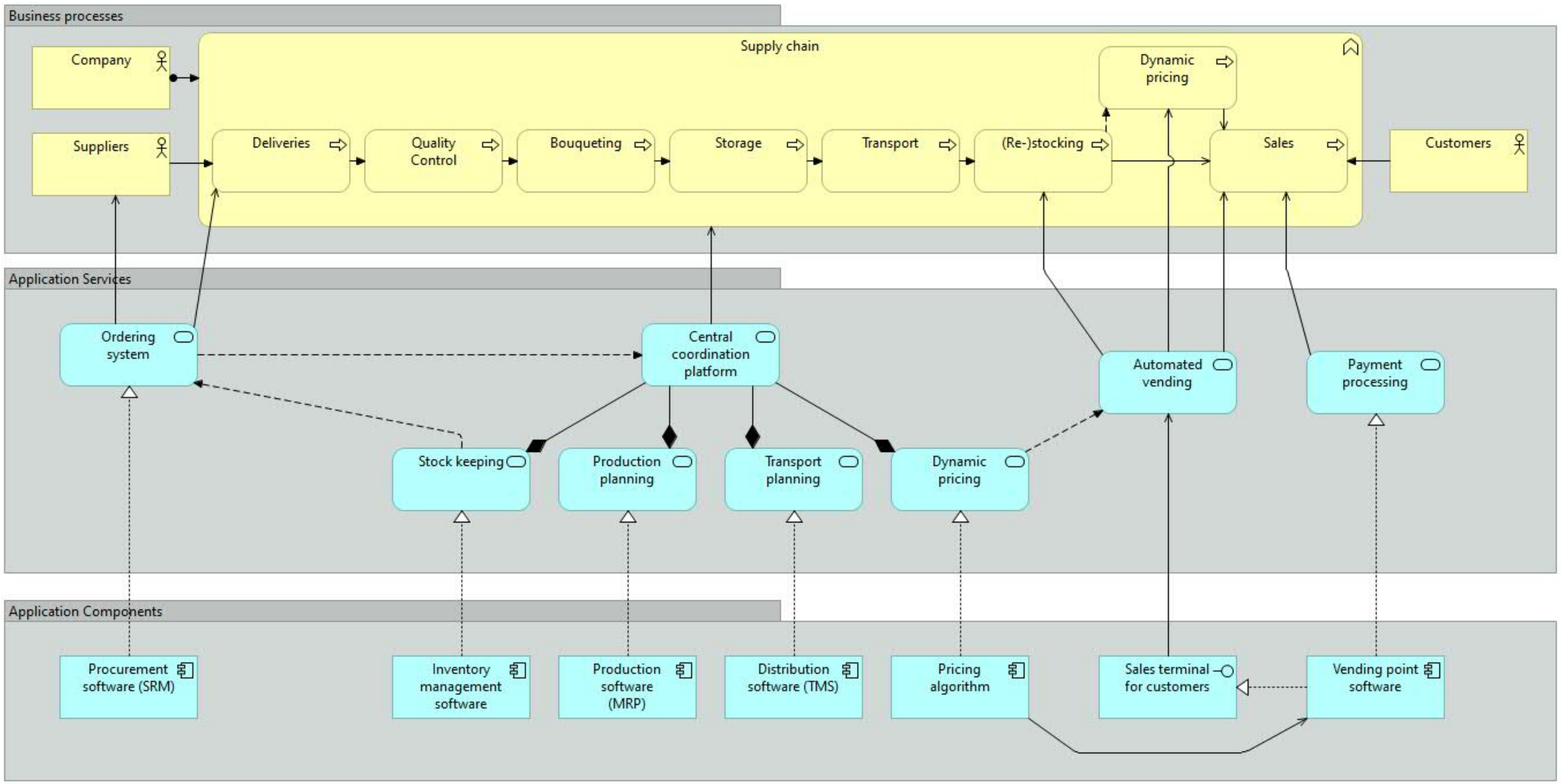

Figure E.6: An Enterprise Architecture model of the digital systems design for design alternative 4A: preparing for growth (make-to-stock).

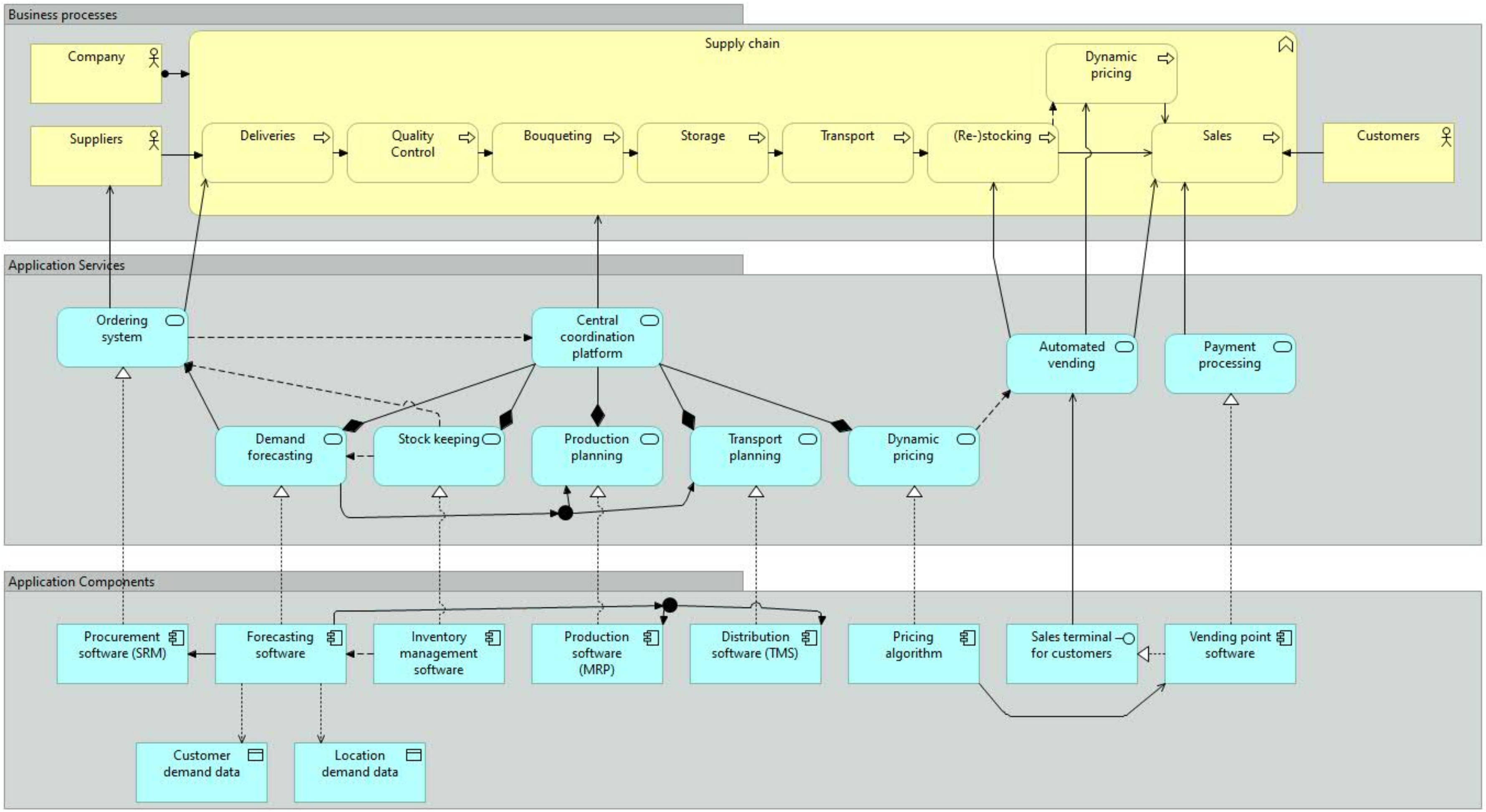

Figure E.7: An Enterprise Architecture model of the digital systems design for design alternative 4B: preparing for growth (make-to-order).

F

Full MCDA calculations

Table F.1: The full calculations and weights used in the multiple criteria decision analysis for the physical supply chain.

		Reliability				Responsiveness				Agility				Cost				Assets				Environmental				Total			
Function description	Weight	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Internal receival	4	4	4.5	4.5	4	4	4	4	4	5	3	3	5	4	3	3	4	3	4	4	3	3	3	3	3	92	86	86	92
External receival	3	4	4	4	4	4	4	4	4	5	5	5	5	4	4	4	4	3	3	3	3	3	3	3	3	69	69	69	69
Prepare internal	4	4	4	4	4	5	3	3	3	2	5	5	5	5	4	4	4	3	4	4	4	4	3	3	3	92	92	92	92
Prepare external	2	4	4	4	4	5	5	5	5	2	2	2	2	5	5	5	5	3	3	3	3	4	4	4	4	46	46	46	46
Move	5	4.5	4.5	4.5	4.5	4	4	4	4	4.5	4.5	4.5	4.5	4	4	4	4	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	120	120	120	120
Log internal receivals	3	4	4	4	4	3	3.5	3.5	3.5	4	4	4	4	4	3.5	3.5	3.5	3	3	3	3	5	4.5	4.5	4.5	69	67.5	67.5	67.5
Log external receivals	2	4	4	4	4	3	3.5	3.5	3.5	4	4	4	4	4	3.5	3.5	3.5	3	3	3	3	5	4.5	4.5	4.5	46	45	45	45
Perform QC	4	5	5	5	5	3	3	3	3	4	4	4	4	3	3	3	3	5	5	5	5	3	3	3	3	92	92	92	92
Log QC	2	4	4	4	4	3	3.5	3.5	3	4	4.5	4.5	4	4	3	3	4	3	3	3	3	5	4.5	4.5	5	46	45	45	46
Dispose waste (production)	1	4	4	4	4	4	2	4	4	3	4	3	3	2	3	2	2	3	4	3	3	4	5	4	4	20	22	20	20
Sell on spot market	4	4	3.5	4	4	4	3	3	3.5	5	4	5	5	2	3	3	2.5	4	4.5	4	4	3	3.5	3	3	88	86	88	88
Collect packaging material	1	3	3	3	3	3	3	3	3	2	2	2	2	4	4	4	4	4	4	4	4	4	4	4	4	20	20	20	20
Produce bouquets	5	4	5	4	5	4	3	4	3	3	5	3	5	2	4	2	4	4	3	4	3	3	4	3	4	100	120	100	120
Prepare bouquets for storage	1	4	4	4	4	5	4	5	3	2	1	2	5	5	1	5	4	3	5	3	4	4	2	4	3	23	17	23	23
Log storage	1	4	4	4	4	3	3	3	3	4	4	4	4	4	4	4	4	3	3	3	3	5	5	5	5	23	23	23	23
Store	5	4.3	4.3	4.3	4.3	4	3.7	4	3.7	4	4.3	4	4.3	3.3	2.7	3.3	2.7	3.3	4	3.3	4	2.7	2.7	2.7	2.7	108	108	108	108
(Un-)load vehicle	4	5	5	5	5	3	3	3	3	4	4	4	4	5	5	5	5	3	3	3	3	4	4	4	4	96	96	96	96
Move vehicle	5	5	4.5	4.5	4.5	4.5	3.5	4	3.5	4.5	4.5	4	4.5	2.5	3.5	2.8	3.5	4	3	3.3	3	2	4	3	4	113	115	108	115
Receive vehicle	1	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	21	21	21	21
Service vending point	4	4	4	4	4	4	3.5	3.5	3.5	2.5	4	4	4	3	3.5	3.5	3.5	2	3	3	3	2.5	3	3	3	72	84	84	84
Stocking	4	4	4	4	4	4	5	5	4	4	3	3	4	3	4	4	3	3	2	2	3	3	3	3	3	84	84	84	84
Dispose waste at vending point	1	5	5	4	5	4	4	3	4	5	5	2	5	4	4	1	4	2	2	4	2	4	4	3	4	24	24	17	24
Sell to consumer	5	4	4.3	4	4	4	3	3.5	4	2	3	2.5	2	5	3.3	4.5	5	4	4.3	4	4	3	3	3	3	110	105	108	110
Provide proof of delivery	1	4	4.5	4.5	4	5	4.5	4.5	5	4	4	4	4	5	4.5	4.5	5	3	2.5	2.5	3	4	4	4	4	25	24	24	25
Log sales	1	4	4	4	4	3	3.5	3.5	3	4	4.5	4.5	4	4	3	3	4	3	3	3	3	5	4.5	4.5	5	23	22.5	22.5	23
		308	313	307	311	285	258	272	261	271	291	276	304	266	262	258	274	246	254	252	249	246	256	244	255	1622	1634	1608	1654
		4.2	4.3	4.2	4.3	3.9	3.5	3.7	3.6	3.7	4	3.8	4.2	3.6	3.6	3.5	3.8	3.4	3.5	3.5	3.4	3.4	3.5	3.3	3.5	3.7	3.7	3.7	3.8