

Master's Thesis – Master Sustainable Business and Innovation

The Circular Transition of the Dutch Carpet Industry

A Sectoral Innovation System approach

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Abstract

Introduction

The shift to a Circular Economy presents a solution to the growing problems of waste accumulation and resource depletion, especially for resource-intensive businesses. The Dutch government therefore has set to goal of establishing a Circular Economy by 2050. Even though the Netherlands is one of the world's top producers of carpet, there is a noticeable lack of research and policy on the circular transition of this sector. To comply with becoming fully circular by 2050 in the Netherlands, the carpet industry must be considered. This research aims to fill the gap in the current literature by going beyond the end-of-life carpets, focusing on the implementation of all circular strategies, taking into account a systems perspective and analysing the drivers for the circular transition within the innovation systems perspective, resulting in the following RQ: **How can the implementation of circular strategies be stimulated in the Dutch carpet industry?**

Theory

Sectoral Innovation System theory and the Waste Hierarchy provide the theoretical lens used in this study.

Methods

The research is conducted by analysing 13 semi-structured interviews and desk research. Data analysis consisted of mapping the structural elements of the Innovation System, followed by a structural-functional analysis. This provided insights into the current system and its functioning.

Results

The results section provides an overview of the current system and its functioning. Drivers and barriers in the implementation of circular strategies of the Dutch carpet industry are identified. Additionally, the interdependencies between these different driver and barriers are described.

Discussion

This study expands the limited literature available on circularity in carpet, and contributes to IS literature highlighting the importance of analysing drivers and demonstrating the interdependencies between drivers and barriers. The results of this study guide practical application for carpet companies and other actors. There seems to be a particular need for action from the government, as this research shows that policy is one of the deciding factors for companies to invest in circularity.

Conclusion

The conclusion shows the key drivers and barriers to implementing circular strategies in the carpet industry. It shows that there is a lack of guidance for this by the government, resulting in a lack of experimentation, lack of knowledge sharing and lack of knowledge diffusion by industry actors. On the other hand, even though little guidance was provided by the government, this still resulted in a wave of entrepreneurial activity, network formation, knowledge development and knowledge dissemination.

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Abbreviations

CE = Circular Economy

IS = Innovation System

SIS = Sectoral Innovation System

TIS = Technological Innovation System

MIS = Mission-Oriented Innovation System

RIS = Regional Innovation System

MLP = Multi-Level Perspective

TM = Transition Management

NIS = National Innovation System

ECRA = European Carpet and Rug Association

BVP = Branche Vereniging Projectinrichting (Industry association of project furnishing)

PBL = Planbureau voor de Leefomgeving (Netherlands Environmental Assessment Agency)

CPR = Construction Products Regulation

CSRD = Corporate Sustainability Reporting Directive

EPR = Extended Producer Responsibility

NDA = Non-Disclosure Agreement

EPD = Environmental Product Declaration

1. Introduction

Resource depletion and continuously growing waste flows pose serious problems (Köhler et al., 2019). Still, most of our society is based on producing, using and disposing in a linear way (Sariatli, 2017). This highlights the need for a sustainability transition (Geissdoerfer et al., 2017; Sariatli, 2017; van Ewijk & Stegemann, 2020). A proposed solution is the concept of a Circular Economy (CE) in which product lifetimes are prolonged and waste serves as a resource for new products (Geissdoerfer et al., 2017; Sariatli, 2017).

In 2016 the Dutch government set out a program with the aim of establishing a CE by 2050 (Ministry of Infrastructure and Water Management et al., 2021). In the following years, sector-specific plans were written to guide this systemic transition. One of these sectors is the Dutch textiles sector. Although the policy program gives the impression that it is targeting the whole textiles sector, the Dutch carpet industry seems to be excluded (*Beleid Duurzaam En Circulair Textiel – Afval Circulair*, n.d.; Beleidsprogramma circulair textiel 2020 – 2025, 2020). This is striking, given that the Netherlands is part of the top four leading carpet producing countries worldwide (Behne, 2020; Woudt, 2021) and shares its leading position in the European Union with Belgium and the UK (Hilton, 2018). Tufted carpets are most commonly produced in the Netherlands (*StatLine – Goederen; grensoverschrijding, GN (8 digits, afdeling VIII-XV), landen*, 2023). Tufting is a technology the Netherlands quickly adopted since its invention in the United States in the 1950s (Geenhuizen & van der Knaap, 1994). Today, the Netherlands is home to twelve active carpet producers producing about 180 million square meters of carpet annually of which 85% is exported within the European Union (de Munck & de Waal, 2020; Peter Koppert & Ben Römgen, 2012).

While many of these carpet producers offer circular products in their portfolio, the actual scale of circular practices within these firms remains unknown (Changing Markets Foundation, 2018; Deutsche Umwelthilfe e.V., 2017). What is known however is that Europe generates 1.6 million tons of post-consumer carpet waste each year, 60% of which is landfilled, 37–39% is incinerated, and only 1–3% is recycled (Deutsche Umwelthilfe e.V., 2017; Hilton, 2018). Academic literature offers several explanations as to why the material cycles of carpet are not sufficiently closed. As Lama et al. (2022) state “the current structure, composition, and assembly of complex products such as carpets prevent closing these material cycles and, thus, pose challenges in reaching circularity” (p.1). This is in line with the academic studies by Demarteau et al. (2022) and Lama et al. (2022) highlighting the problem the inextricability of carpet poses for recycling. Further research points to the presence of toxins disruptive to human health and the environment in carpets (Changing Markets Foundation, 2018), thus hindering the reuse of carpets (Changing Markets Foundation, 2018; Lama et al., 2022). The same report pinpoints a lack of comprehensive

chemicals regulation and shows failings of self-regulation within the carpet industry (Changing Markets Foundation, 2018).

Turning to existing academic literature on this subject, literature on the necessary circular transition of the carpet industry from a systemic point of view appears to be lacking. Similarly to the Dutch policy program for circular textiles, literature on circular textiles focuses for the most part on fashion (Fischer & Pascucci, 2017; Kazancoglu et al., 2020; Reike et al., 2023). The limited number of papers on CE and carpet are mostly studies about the end of life of carpets, e.g. alternative applications for carpet waste (Cobra et al., 2021; Lama et al., 2022), recycling technologies (Keijer et al., 2019; Nielsen & Hakala, 2022) and material flow analysis (Cunningham & Miller, 2022) or case studies showcasing best practices of specific business models or strategies (Cramer, 2005; Howard et al., 2022; Velter et al., 2020). By focusing on the end of life of carpets, they do not address the potential for circularity, remaining in a linear way of thinking. Furthermore, these studies are examining pilot projects – this poses the crucial question about the implementation or lack thereof, of circular initiatives in the carpets industry. Additionally, a systems perspective is in most cases overlooked (for exceptions see Howard et al. 2022, Velter et al. 2020), as most studies view businesses as independent entities. This is similarly true of the literature on circular textiles (Reike et al., 2023).

To address these shortcomings of the current literature, this study aims to 1) go beyond the end of life of carpets, 2) focus on the implementation of circular initiatives and 3) take a systems perspective, by analysing the Dutch carpet industry from a systems perspective and identifying drivers and barriers in the circular transition of this industry. Hence, the following research question is formulated:

How can the implementation of circular strategies be stimulated in the Dutch carpet industry?

To answer this the following sub-questions have been formulated:

- 1. What is the current state of the use of circular strategies in the Dutch carpet industry?**
- 2. What are the drivers and barriers in the implementation of circular strategies in the Dutch carpet industry?**

Given that the researcher has not found current research that addresses the scope of circular practices in the Dutch carpet industry, this study started by mapping current practices building on expert knowledge of stakeholders in the industry. This was followed by an explorative qualitative analysis of the drivers and barriers within the system, literature on circular strategies and sectoral innovation systems, thereby also contributing to the further advancement of these theories. Semi-structured stakeholder and expert interviews have been used to obtain data. The thesis will conclude with an overview of key

drivers and barriers to be acted upon as to simulate the implementation of circular strategies in the industry.

Beyond filling the gap in research on a crucial Dutch industry, by taking a systems approach, this research will contribute to a broader body of literature on circular transitions, by providing novel insights on how drivers and barriers within a sectoral system can be identified. By employing a novel combination of theories on circular strategies and sectoral innovation systems, this thesis aims to work within a framework that may be modified and applied in other case studies examining circular industries. From a practical perspective, by critically examining the current state of circularity in the Dutch carpet industry and implementation efforts, this study aims to provide valuable information for the Dutch government and industry actors to incentivise the industry's circular transition and contribute to achieving its goal of establishing a fully CE by 2050.

2. Theory

As this thesis explores the circular transition of the Dutch carpet industry, several theoretical concepts are relevant to address. One overarching concept is the CE, which is gaining momentum as a key contributor to achieving the sustainable transition (Corona et al., 2019; Reike et al., 2018). However, despite its potential, circularity is not yet widespread in the carpet industry, making it an innovative concept that requires to be implemented further. The transition towards a CE is recognized as a systemic process that requires holistic action (Kirchherr et al., 2017). In light of these considerations, employing an innovation system theory approach can provide a valuable lens for understanding and facilitating the transition towards CE (de Jesus & Mendonça, 2018).

2.1. Circular Economy

The CE concept is gaining traction among governments, academics, businesses, and citizens as a critical step in the necessary sustainability transition (Corona et al., 2019; Reike et al., 2018). Transitioning to a CE requires moving from the conventional linear economic model (take-make-dispose) to a circular model which seeks to maximize the value and use of resources within production systems (Milios, 2021; Neves & Marques, 2022). A multitude of studies have contributed to the scientific literature on CE, but the concept is still in its early stages and numerous approaches exist (Charef, 2022). Based on 114 definitions Kirchherr et al. (2017) formed the definition of CE that is adopted in this study, namely CE is:

an economic system that replaces the ‘end-of-life’ concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes. It operates at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, thus simultaneously creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations. (p 229.)

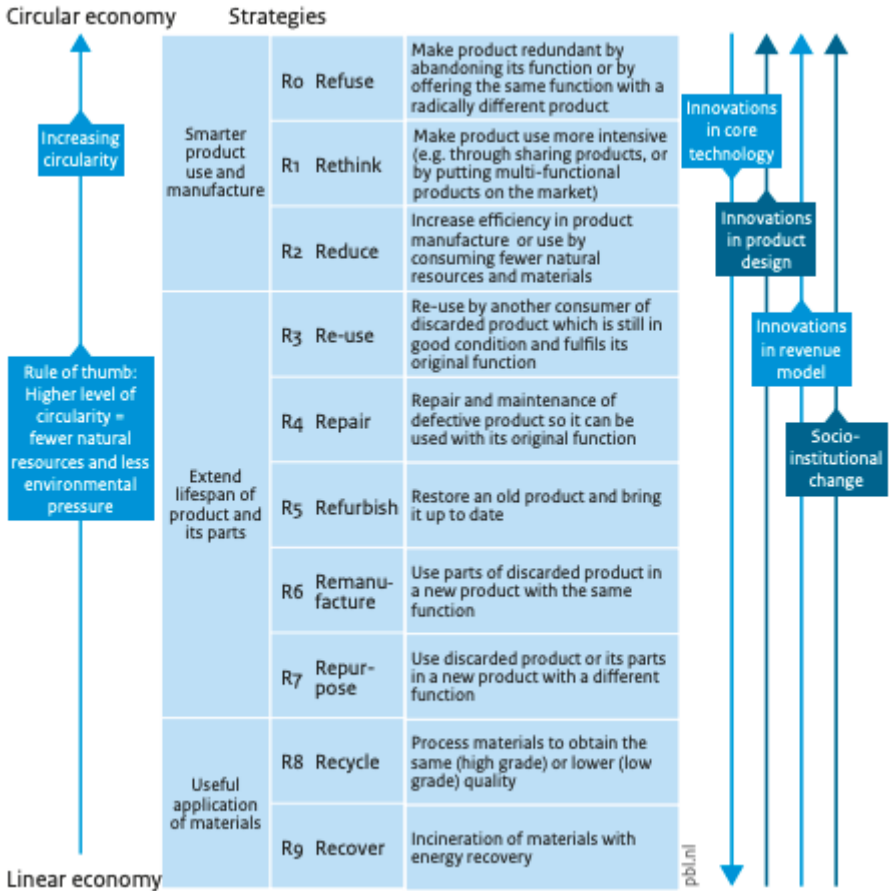
Kirchherr et al. (2017) emphasize a systems perspective to be one of the fundamental principles of CE as it necessitates a major shift rather than gradual changes in the current system. Currently, the Dutch carpet industry seems to be at the beginning of this systems change. Circular initiatives are apparent (Howard et al., 2022; Velter et al., 2020) but do not seem to be widely implemented, hence an analysis of the system is necessary to identify drivers and barriers in this circular transition.

2.1.2. Circular strategies

To facilitate the operationalization of CE, circular strategies are used by the Dutch government (Ghisellini et al., 2016; Reike et al., 2018). One of which is waste hierarchy

(Potting et al., 2017). Waste hierarchy is a commonly used prioritization of different CE strategies and an imperative part of waste legislation, both in the EU and worldwide (Potting et al., 2017; Zhang et al., 2022). It prioritizes different options for managing waste, from prevention and reuse to recycling and disposal (Potting et al., 2017; Reike et al., 2018; Zhang et al., 2022). This study will use the waste hierarchy framework by Potting et al.(2017), as it has been used in Dutch governmental programs and it comprises a combination of existing frameworks (Kirchherr et al., 2017). The framework consists of a 10-step hierarchy of strategies that contribute to the realization of CE (Potting et al., 2017). Figure 1 gives an overview of the 10 R-strategies.

Figure 1
R-framework



Note. Reprinted from *Circular Economy: Measuring innovation In the product chain*, by J. Potting et al., 2017, p. 5.

The hierarchy of the R-strategies is based on their priority, with R0 obtaining the highest level of circularity by, using the least number of natural resources and creating the least amount of environmental pressure (Potting et al., 2017). The strategies are categorized into three groups based on the size of the resource loop that the chosen strategy creates (Reike et al., 2018).

R0–R2 obtain the highest level of circularity and are part of the category *smarter product use and manufacture* containing the short loops in which the product stays close to the user and its function (Reike et al., 2018). R3–R7 are strategies with medium–long loops and are categorized in *extend lifespan of product and its parts*. This is done by upgrading products (Reike et al., 2018). Finally, R8 and R9 obtain the lowest level of circularity corresponding to the longest resource loops where a product loses its initial function (Reike et al., 2018). This category is called *useful application of materials*. Although this category obtains the lowest level of circularity, the resulting resources can be used in higher–level R–strategies (Reike et al., 2018). R–strategies can be employed consecutively or simultaneously (Morsetto, 2020). In the context of this study, the R–strategies provide a useful framework to map the current state of circular practices in the Dutch carpet industry.

2.1.3. Circularity in the carpet industry

Academic literature on CE relating to carpets is scarce, additionally, the concept of circularity is often not specifically mentioned. Although most academic studies focus on lower–level circularity strategies for the end–of–life of carpets (e.g., Keijer et al., 2019; Velter et al., 2020), some examples of rethinking and reducing can be found in studies on the carpet industry (Howard et al., 2022; Lama et al., 2022; Nielsen & Hakala, 2022). Table 1 provides an overview of circular strategies mentioned in the literature on carpets. This forms the theoretical foundation which is used in the data analysis of this study.

Table 1
R–strategies in the context of the Carpet Industry

	Example of R–strategy in the Carpet Industry	Mentioned by:
<i>R0 Refuse</i>	–	
<i>R1 Rethink</i>	Rethinking the business model by leasing carpet.	(Howard et al., 2022; Nielsen & Hakala, 2022)
<i>R2 Reduce</i>	Reducing the use of (primary) material in production by using alternative materials and more recycled content.	(Lama et al., 2022)
<i>R3 Re–use</i>	–	
<i>R4 Repair</i>	–	
<i>R5 Refurbish</i>	–	
<i>R6 Remanufacture</i>	–	
<i>R7 Repurpose</i>	Repurposing recycled carpet waste as reinforcement of cement and limestone.	(Cunningham & Miller, 2022; Lama et al., 2022)
	Repurposing old carpets in noise barriers for highway and infrastructure applications.	(Lama et al., 2022)

<i>R8 Recycle</i>	Repurposing carpet waste as alternative raw material in the production of acoustic panels.	(Lama et al., 2022)
	Enabling recycling by redesigning the carpet product (e.g. removing hazardous substances from carpet tiles) and introducing a take-back scheme.	(Howard et al., 2022)
	Recycling (automotive) carpet waste to develop waste-based polymer composite materials.	(Cobra et al., 2021)
	Enabling recycling by redesigning the carpet-making process to produce a mono-material carpet in a collaboration between DSM and Niaga.	(Keijer et al., 2019; Velter et al., 2020)
	Enabling recycling of nylon carpet fibers through a partnership with chemical companies.	(Nielsen & Hakala, 2022)
<i>R9 Recover</i>	Enabling recycling due to a technological development making more efficient separation of carpet tile components possible.	(Nielsen & Hakala, 2022)
	Recovering energy by using carpet waste as feedstock for electricity or heat generation.	(Cunningham & Miller, 2022)

Despite a systems perspective being a fundamental principle of CE (Kirchherr et al., 2017), a systems perspective in the CE literature on carpet is in most cases overlooked. Exceptions are the studies of Howard et al. (2022) exploring CE adoption for small-medium enterprises, and Velter et al. (2020) exploring changes in organizational boundaries during sustainable business model innovation. Both studies found difficulties in CE implementation at a systems level. In Howard et al.'s (2022) case study, the collaboration of a carpet producer with a supplier to remove environmentally unstable substances from one of their products proved difficult, because the supplier was reluctant to share information. Furthermore, Velter et al. (2020) notes that a collective understanding of the importance of sustainability was required to close the loop in a collaborative project between DSM and Niaga developing a mono-material carpet. The study concludes that working together with partners at the end of the value chain is important in the circular transition. Howard et al. (2022) and Velter et al. (2020) thus demonstrate the need for a systemic perspective enabling the analysis of relationships between stakeholders along the value chain for this study on circularity in the carpet industry.

2.2. Systems perspective on circular transitions

In general, a system is an analytical model of reality consisting of elements that interact with each other (Markard & Truffer, 2008). Transitioning to a CE entails a change in

systems (Milios, 2021). Scholars, therefore, agree that the transition to a CE necessitates systemic action, meaning that all system actors (e.g., policymakers, businesses, educational institutions, consumers, etc.) must be involved to accomplish this transition (Ghisellini et al., 2016; Milios, 2021). Established theoretical frameworks that are used to study circular transitions come from the field of sustainability transitions (Köhler et al., 2019), including the Multi-Level Perspective (MLP), Innovation Systems (IS), and Transition Management (TM). The MLP framework emphasizes the interplay between niche innovations, regime structures, and the broader socio-technical landscape. It theorizes that an innovation can mature enough in its protective niche to overthrow regime structures when landscape changes put a strain on the regime, thereby establishing systemic change (Geels & Schot, 2007). IS, on the other hand, focuses on the interplay between different actors, institutions, and networks involved in innovation processes (Hekkert et al., 2007; Köhler et al., 2019). Finally, TM is a framework focused on policy that proposes four consecutive steps for policymakers to shape transitions (Köhler et al., 2019). The fundamental principle of TM is centred around gathering relevant stakeholders for collaboration instead of competition to enable transitions (Köhler et al., 2019). TM assumes that the process of governance to reach desired goals can be planned and coordinated from the start (Geels & Schot, 2007). Since industry-specific plans for the circular transition of the carpet industry are currently lacking, a TM approach is not applicable to this study.

Both the MLP and the IS framework are arguably suitable for this study, since both frameworks aid in the comprehension of innovation and transformation processes (Markard & Truffer, 2008). However, when it comes to the roles and interdependencies different agents and institutions have in innovation and transition processes the MLP proves to be less effective than the IS approach (Markard & Truffer, 2008). In the context of the circular transition of the carpet industry, it is important to analyse the relationships between different agents along the value chain, as has been highlighted by the studies of Howard et al. (2022) and Velter et al. (2020). Hence, an IS theory is better suited for this study.

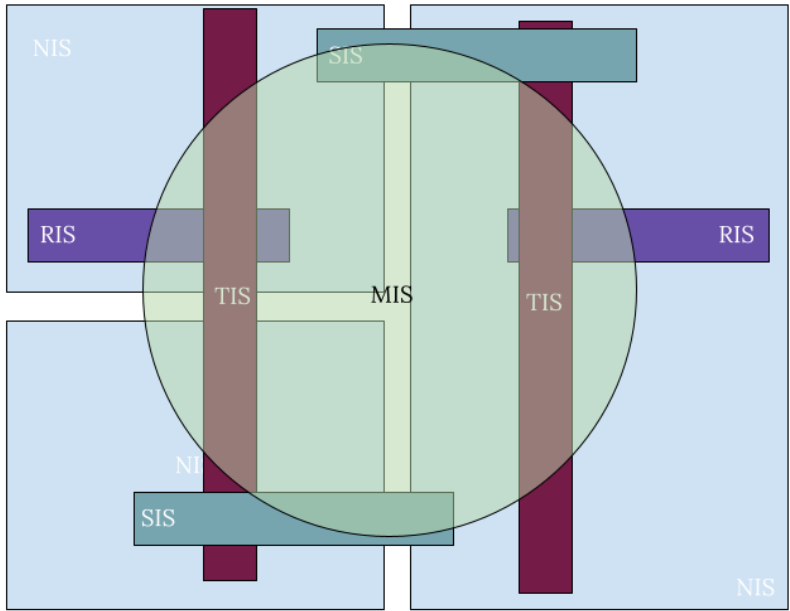
2.2.1. Innovation Systems

The IS framework provides a comprehensive and flexible approach for studying the emergence and growth of new technological fields and industries, accounting for the complex interactions between actors, institutions, and technologies in innovation processes (Markard et al., 2015). Moreover, the IS framework has been successfully applied to study sustainability transitions in other sectors (Jacobsson & Bergek, 2011; Köhler et al., 2019), suggesting that it can be adapted to the specific context of the carpet industry.

IS can be viewed as a set of agents and institutions and the relationships amongst them, that develop, diffuse and utilize innovations (Edquist, 2006; Malerba, 2002). Agents

commonly entail different organisations and institutions can be considered the (implied) principles that govern the behaviour of actors (e.g. regulations or sociocultural norms) (Markard & Truffer, 2008). IS theory emphasizes that firms do not innovate in isolation, rather it considers it to be an interactive collective process of the system’s actors (Malerba, 2005). The multitude of relationships between actors, institutions and the combination of both influence the innovation process since actors can for instance compete or collaborate and institutions can conflict or complement each other (Markard & Truffer, 2008). These influences on the innovation process are similarly visible in the studies of Howard et al. (2022) and Velter et al. (2020), considering their notion of collaborative challenges and the need for a collective understanding of the importance of sustainability in the implementation of circularity in the carpet industry. IS dynamics are therefore especially interesting in the context of this study, since the analysis of these dynamics may enable the identification of drivers and barriers in the implementation of circular strategies, bringing forward the possibility of modifying the innovation process (Hekkert et al., 2007). IS can be delineated based on its system boundaries, such as national, regional, sectorial, technological and mission oriented (Hekkert et al., 2020). The overlap of these IS’s are illustrated in figure 2.

Figure 2
Different types of Innovation Systems and their overlap



Note. Adapted from *Developing and applying the Mission-oriented Innovation Systems (MIS) approach*, by J. Wesseling & N. Meijerhof, 2021, p. 9.

A National Innovation System (NIS) operates within national borders, within a Regional Innovation System (RIS) can exist. The Sectoral Innovation System (SIS) is delineated based on its sector or industry and commonly crosses geographical boundaries and thus can exist within multiple NISs (Markard & Truffer, 2008). Because the Technological

Innovation System (TIS) is focused on a specific technology, it can exist and overlap with the other ISSs. The system boundaries of the recently developed Mission-Oriented Innovation System (MIS) approach consist according to Hekkert et al. (2020) of “the network of agents and set of institutions that contribute to the development and diffusion of innovative solutions with the aim to define, pursue and complete a societal mission” (p. 77). A MIS can thus overlap all other ISSs, but actors who are not contributing to the societal mission are excluded from the MIS. System delineation is mainly based on the research question and goal of analysis (Markard & Truffer, 2008). Since this research aims to examine measures to improve the implementation of circular strategies in the Dutch carpet industry, this study will adopt a SIS approach.

2.2.2. Sectoral Innovation System

A SIS approach allows for the analysis of the implementation of innovation within a sector or industry (Koasidis et al., 2020; Ramirez & Restrepo, 2012; Wesseling & Van der Vooren, 2017). In the context of this study, the SIS approach is applied to explore how the implementation of circular strategies in the Dutch carpet industry can be enhanced. Malerba’s (2002) definition of a SIS is most commonly used:

A set of new and established products for specific uses and the set of agents carrying out market and non-market interactions for the creation, production and sale of those products. Sectoral systems have a knowledge base, technologies, inputs and demand. The agents are individuals and organizations at various levels of aggregation, with specific learning processes, competencies, organizational structure, beliefs, objectives and behaviours. They interact through processes of communication, exchange, co-operation, competition and command, and their interactions are shaped by institutions. A sectoral system undergoes processes of change and transformation through the co-evolution of its various elements.
(p.248)

These elements as Malerba calls them are commonly referred to as the structural components of an IS and consist of actors, institutions, networks¹ and infrastructure. Table 2 provides an overview of the structural dimensions and its definitions.

¹ Sometimes referred to as interactions (Wieczorek & Hekkert, 2012).

Table 2
Structural dimensions of an Innovation System

Structural dimensions	Definition	Subcategories
Actors	Individuals, organisations involved in economic activities within the innovation system, categorised based on their roles in economic activities.	<ul style="list-style-type: none"> • Civil society • Companies: start-ups, small and medium-sized enterprises, large firms, multinational companies • Knowledge institutes: universities, technology institutes, research centres, schools • Government • NGOs • Other parties: legal organisations, financial organisations/banks, intermediaries, knowledge brokers, consultants
Institutions	Common habits, routines, shared concepts, rules, norms, and strategies used by humans in repetitive situations (soft institutions) or organized by rules, norms, and strategies (hard institutions).	<ul style="list-style-type: none"> • Hard: rules, laws, regulations, instructions • Soft: customs, common habits, routines, established practices, traditions, ways of conduct, norms, expectations
Networks	Cooperative relationships and links between actors in the innovation system. Networks can be analysed at the level of both networks and individual contacts, focusing on dynamic interactions and relationships	<ul style="list-style-type: none"> • At level of networks • At level of individual contacts
Infrastructure	Physical infrastructure includes tangible elements such as buildings, roads, telecom networks, and machines. Knowledge infrastructure encompasses knowledge, expertise, know-how, and strategic information. Financial infrastructure includes subsidies, financial programs, grants, etc.	<ul style="list-style-type: none"> • Physical: artefacts, instruments, machines, roads, buildings, networks, bridges, harbours • Knowledge: knowledge, expertise, know-how, strategic information • Financial: subsidies, fin programs, grants etc.

Note. Adapted from *Systemic instruments for systemic innovation problems: A framework for policy makers and innovation scholars*, by Wieczorek and Hekkert., (2012).

System transformation is analysed in SIS literature by identifying systemic problems through the connections between the structural components (Faber & Hoppe, 2013; Malerba, 2002). Systemic problems arise when the structural components inhibit the functioning of the system (Wesseling & Van der Vooren, 2017).

In literature systemic problems have a multitude of different names, like system failures (Klein Woolthuis et al., 2005), barriers (Suurs et al., 2010) or blocking mechanisms (Bergek et al., 2008). Alongside blocking mechanisms Bergek et al. (2008) presents inducement

mechanisms or drivers (Suurs et al., 2010), which, opposite of blocking mechanisms, drive system functioning. Inducement mechanisms have not received much attention in literature, since scholars value the identification of systemic problems more from a policy standpoint (Nevzorova & Karakaya, 2020). However, focusing only on systemic problems could conceal present strengths and provide unfavourable feedback on the functioning of the system (Hellsmark et al., 2016). Acknowledging the intricacy and variety of titles, this study will use ‘drivers’ to refer to factors in which the structural components strengthen the functioning of the system, and ‘barriers’ to refer to factors in which the structural components inhibit the functioning of the system.

Several scholars argue that analysing the structural components to identify drivers and barriers alone does not allow good insight into the source of barriers, as it falls short of a structured approach to incorporate the influence of these barriers on key innovation processes (Bergek et al., 2008; Wieczorek & Hekkert, 2012). Wesseling and Van der Vooren (2017) faced a similar problem in their SIS on the transformation of the Dutch concrete industry. They addressed this by adopting a structural–functional approach. This approach adds an analysis of the system functions after mapping the structural characteristics and dynamics of an IS (Bergek et al., 2008). The system functions capture the dynamics of several key processes (functions) and are the intermediate variables between structure and system performance (Bergek et al., 2008; Jacobsson & Bergek, 2011). Explanations of each system function are elaborated on in table 3. Regarding this study, performing a structural–functional analysis allows for the identification of drivers and barriers and their source in the implementation of circular strategies in the Dutch carpet industry.

Table 3
System functions

System Function	Description
Entrepreneurial activities	Entrepreneurial experimentation and commercialization of innovations (e.g. pilots)
Knowledge development	Learning by searching and doing (e.g. R&D)
Knowledge diffusion	Exchange of tacit and codified knowledge in formal and informal networks; learning by interacting and by using
Guidance of the search	(In)direct selection of technological trajectories or designs in transformation or development processes
Market formation	Creation of protected niches (through regulations, policy and standards) and subsequently mass market demand
Resources mobilization	Allocation of financial, human and other resources to fulfil other system functions
Creation of legitimacy	Create legitimacy for a technological trajectory: includes lobbying

Note. Reprinted from *Functions of innovation systems: A new approach for analysing technological change*, by Hekkert et al., 2007.

However, the structural–functional approach is predominantly used in assessing the system growth of emerging TIS (Bergek et al., 2008; Wesseling & Meijerhof, 2021). This differs from the system addressed in this study, which is an established industry and thus can be seen as a mature SIS. Mature systems are distinguished by significant interconnections among IS components, which may result in barriers causing or strengthening other barriers (Bergek et al., 2008; Kieft et al., 2017). On the other hand, the same could be said about drivers. Drivers could reinforce each other, creating virtuous feedback loops strengthening system development (Hekkert et al., 2007; Reike et al., 2023). In the context of this study, it is therefore important to identify interdependencies between drivers and barriers (Kieft et al., 2017).

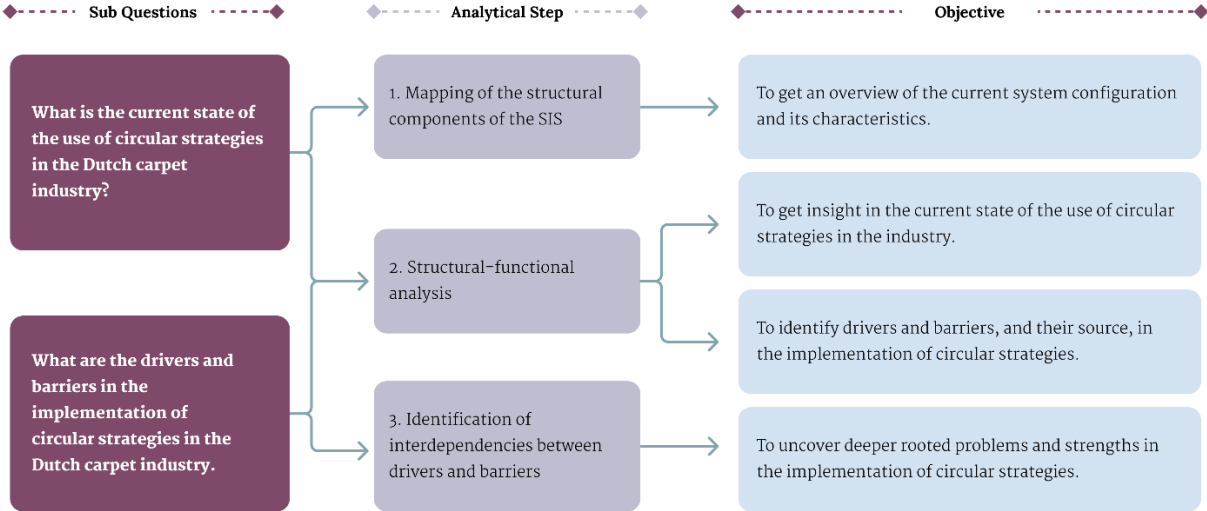
3. Methodology

3.1. Research design

This study aimed to explore how the implementation of circular strategies can be stimulated in the Dutch carpet industry. This was done by analysing its corresponding SIS, as it allows for an analysis of how elements in the carpet industry interact and influence each other in the context of circular strategies (Markard et al., 2015). The scope was therefore focussed on the SIS in which circular strategies within the Dutch carpet industry operate (Markard & Truffer, 2008). The primary geographical focus was the Netherlands, although influences from outside the Netherlands (e.g. export and EU legislation) were also considered.

The research design employed in this study was based on the method combining SIS analysis with a structural-functional approach that has been used in previous studies (Cheong et al., 2020; Vidican et al., 2012; Wesseling & Van der Vooren, 2017). Applying a structural-functional approach to a SIS analysis provides insight in the current system configuration, to answer the first sub-question, and sheds light on the source of drivers and barriers in the implementation of circular strategies (Wieczorek & Hekkert, 2012), to answer the second sub-question. The structural-functional approach constitutes of several analytical steps (Bergek et al., 2008; Wieczorek & Hekkert, 2012). An overview of the analytical steps of this study is provided in figure 3. An additional step was added to examine deeper rooted problems and strengths that are of common occurrence in established industries (Wesseling & Van der Vooren, 2017), like the Dutch carpet industry. This was achieved by means of identifying interdependencies between drivers and barriers, as advised by Wesseling & Van der Vooren (2017) and Kieft et al. (2017).

Figure 3
Analytical steps



The analytical steps in this study were applied by utilizing an exploratory qualitative approach in the data collection, incorporating a combination of desk research and semi-structured expert interviews. A qualitative approach is suitable for this study since it allows for the discovery and investigation of underlying linkages of new phenomena (Bryman, 2016).

Desk research consisting of a review of relevant literature, reports, news publications, and documents related to circular strategies and sustainability in the carpet industry provided the basis for the first analytical step of this study: the mapping of the structural components of the SIS and helped to contextualise the findings throughout the study. In addition to semi-structured interviews with 13 experts representing various stakeholders of the carpet industry have been conducted to complement and verify the desk research. The interviews focussed both on system structure, for analytical step one, and the functioning of the system, to perform analytical step two: the structural-functional analysis of the SIS.

The results of steps one and two consist of an overview of the system structure and its functioning answering sub-question one of this research about the current state of the use of circular strategies in the Dutch carpet industry. Additionally, the structural-functional analysis performed in step two allowed for the identification of systemic problems and their source within the system, in part providing answer to sub-question two of this research about the drivers and barriers in the implementation of circular strategies in the Dutch carpet industry. The answer is completed by performing analytical step three, consisting of the mapping of the systemic problems to identify interdependencies.

3.2. Data collection and sampling

3.2.1. Desk research

To map the preliminary structural components of the SIS desk research was used to collect data. This involved an extensive review of relevant literature, reports, and documents related to circular strategies and sustainability in the carpet industry. Search terms revolved around the carpet or flooring industry, circularity or sustainability and (individual) R-strategies. Searches were performed in Dutch and English. Other relevant documents were collected using the snowballing process.

Additionally, LexisNexis, an online database that includes news publications, has been used to collect data on developments in the Dutch carpet industry, which was necessary for the mapping of the structural components (e.g. company's revenue's and perceptions of actors on circularity). Searches were performed in Dutch over a timeframe of 2000 onwards as to include historical developments shaping today's carpet industry. Results had to relate

to at least one of the circular strategies, circularity or sustainability, in line with the system’s boundaries. An overview of the LexisNexis input is shown in table 4.

Table 4
LexisNexis input

Results had to contain the search term:	Results had to contain at least one of the search terms or synonyms thereof:	Period	Exclusion criteria	Number of hits
Carpet industry	Circular Sustainable Recover Recycle Repurpose Remanufacture Refurbish Repair Re-use Reduce Rethink Refuse	2000- 2023	Documents that do not focus on the Dutch carpet industry Duplicates	16

3.2.2. Interviews

Given the scarcity of research specifically addressing the research question, semi-structured interviews were conducted with experts representing various actors within the SIS around the implementation of circular strategies in the Dutch carpet industry. The objective of the interviews was to gain insight in the current system structure and its functioning, complementing the desk research. To achieve this a commonly used set of diagnostic interview questions recommended in IS literature was adapted to the scope of this study (Wieczorek & Hekkert, 2012).

Forty system actors were contacted for an interview. This resulted in a total of thirteen interviews that were conducted. Based on the results of the desk research potential interviewees within the SIS were identified. The interviewees were purposively selected to ensure a diverse and representative sample of the different types of actors in the SIS under investigation.

Different types of firms along the supply chain (stages from raw material producer till the reuse of products) including small and large companies, industry associations and a policymaker were interviewed. This way, multiple perspectives were gathered. An overview of the types of the types of actors interviewed is provided in table 5.

Table 5
Overview types of actors interviewed

Subcategory actors	Types interviewed, according to the categorisation of Wiczorek and Hekkert (2012)
Civil society	-
Companies	<ul style="list-style-type: none"> • Start-up • Small and medium-sized enterprises • Large firm • Multinational company
Knowledge institutes	<ul style="list-style-type: none"> • Knowledge platform
Government	<ul style="list-style-type: none"> • Policy advisement
NGOs	-
Other	<ul style="list-style-type: none"> • Consultancy • National industry association • European industry association

Interviewees are anonymised, allowing the participants to speak freely during the interviews. Identifiers have been assigned to each interviewee to reference them in this thesis. A considerable amount of interviewees were performing multiple functions e.g. working for a carpet producer and active in an industry association. Listing all functions an actor fulfils would compromise their anonymity, hence only their primary role is provided in the overview. An overview of the interviewees and their primary role is provided in table 6.

Table 6
Overview of interviewees

In text reference by:	
1	Carpet producer 1
2	Carpet producer 2
3	Carpet producer 3
4	Carpet producer 4
5	(White or private) Label seller
6	Wholesaler
7	Retailer
8	Reused carpet retailer
9	Carpet remanufacturer
10	Carpet fitter
11	Project furnisher
12	Consultant
13	Policy advisor

A semi-structured interview guide has been used to conduct the interviews, allowing for probing and follow-up questions to explore the interviewees' perspectives, experiences, and insights on circular strategies in the carpet industry in-depth (Kallio et al., 2016). The

interview guide can be found in appendix A. The guide is based on a commonly used operationalisation scheme used in IS literature and is adapted to focus on circular strategies, as described in the theory section, to research the implementation of circular strategies in the industry. The operationalisation scheme contains guidance on mapping the structural dimensions of the IS as well as diagnostic questions that indicate the performance of the functions. This study deviates from the operationalisation scheme with regards to the assessment of the system functions. The operationalisation scheme describes the assessment of the functions to be carried out by letting the interviewees rate the performance of the functions using a 5-level Likert scale (Wieczorek & Hekkert, 2012). In the first two interviews, interviewees were asked to perform the assessment. Here, it was found that interviewees struggled with the format or did not feel comfortable rating the performance. Hence, the interview guide was adapted asking the interviewees for a more general indication of performance.

The interviews were conducted digitally, via Microsoft Teams, between May 2023 and September 2023. Since Dutch is the native tongue of both the participants and the interviewer, all interviews were conducted in this language allowing for cultural expression and preventing misinterpretations. The interviews had a duration between thirty and sixty minutes. After oral permission interviews were recorded in Microsoft Teams and afterwards transcribed. The informed consent template provided by Utrecht University was used and can be found integrated in the interview guide in appendix A. After thirteen interviews little new information was mentioned and similar statements were made, hence data saturation was reached.

3.3. Data analysis

3.3.1. Mapping of the structural components of the SIS

The information provided by the desk research formed the basis for the preliminary mapping of the structural components of the SIS. First, the supply chain was visualised using Miro software, mapping the system's actors. In a later stage this supply chain was updated using insights from the interviews. Desk research on the historical context of the industry, its regulations, standards, norms and research reports on the industry provided information on the system's institutions and networks which were also updated according to new insights from the interviews.

3.3.3. Structural-functional analysis

In the structural-functional analysis, the performance of the SIS was researched. For this, the software NVivo was used to categorize interview data according to the system's structure and system's functions. Overlap in codes happened frequently since most problems or topics are connected to more than one function. After this, concepts and

themes were coded within each function. Recurring themes have been identified through a deductive approach aligning with the system functions.

3.3.4. Identification of interdependencies between systemic problems

Through mapping systemic problems were defined that hinder the functions in the structural functional analysis. Special attention was given to overlapping codes, possibly indicating interconnecting problems.

3.4. Quality criteria

Validity and reliability are commonly used criteria to assess the quality of research (Bryman, 2016). Internal reliability refers to the consistency in measuring a concept (Bryman, 2016). Internal reliability was addressed by a review of the coding. At the beginning of coding the transcripts a MSc. Industrial Ecology graduate, experienced in qualitative coding, reviewed the coding scheme. The graduate was given a page of a transcript that was beforehand checked not to contain sensitive information and anonymised, and asked to assign codes using the coding scheme. Afterwards, variations were discussed and the coding scheme was adjusted accordingly, thus enhancing the consistency of the coding and enhancing internal reliability.

External reliability concerns the replicability of the study (Bryman, 2016). Since an IS is dynamic and changing over time, meeting this criterion is difficult. Thorough documentation of the research process, including the interview guide, and analysis procedure offers a certain level of external reliability, providing a guide for future researchers to replicate this study.

Internal validity concerns the soundness of the causal relationships established in a study (Bryman, 2016). Several measures have been taken to address the internal validity of this study. First, interviewees were contacted for clarification and verification of conclusions after the data analysis. Second, multiple methods and sources were used triangulating data to cross-verify results and minimize bias. Finally, discussing the results with the MSc. Industrial Ecology graduate, especially the interdependencies between systemic problems, contributed to internal validity.

External validity relates to the generalisability of the findings of a study (Bryman, 2016). By purposefully selecting a diverse range of interviewees representing the SIS under investigation, the potential to generalise findings to a similar SIS is enhanced.

4. Results

The following section starts with a description of the SIS of the Dutch carpet industry. First, its supply chain and other actors involved were described. Subsequently, the institutions and networks were discussed. After this system description, the performance of each system function was reviewed to identify systemic problems. Lastly, this chapter provides an analysis of interdependencies between these problems.

4.1. System analysis

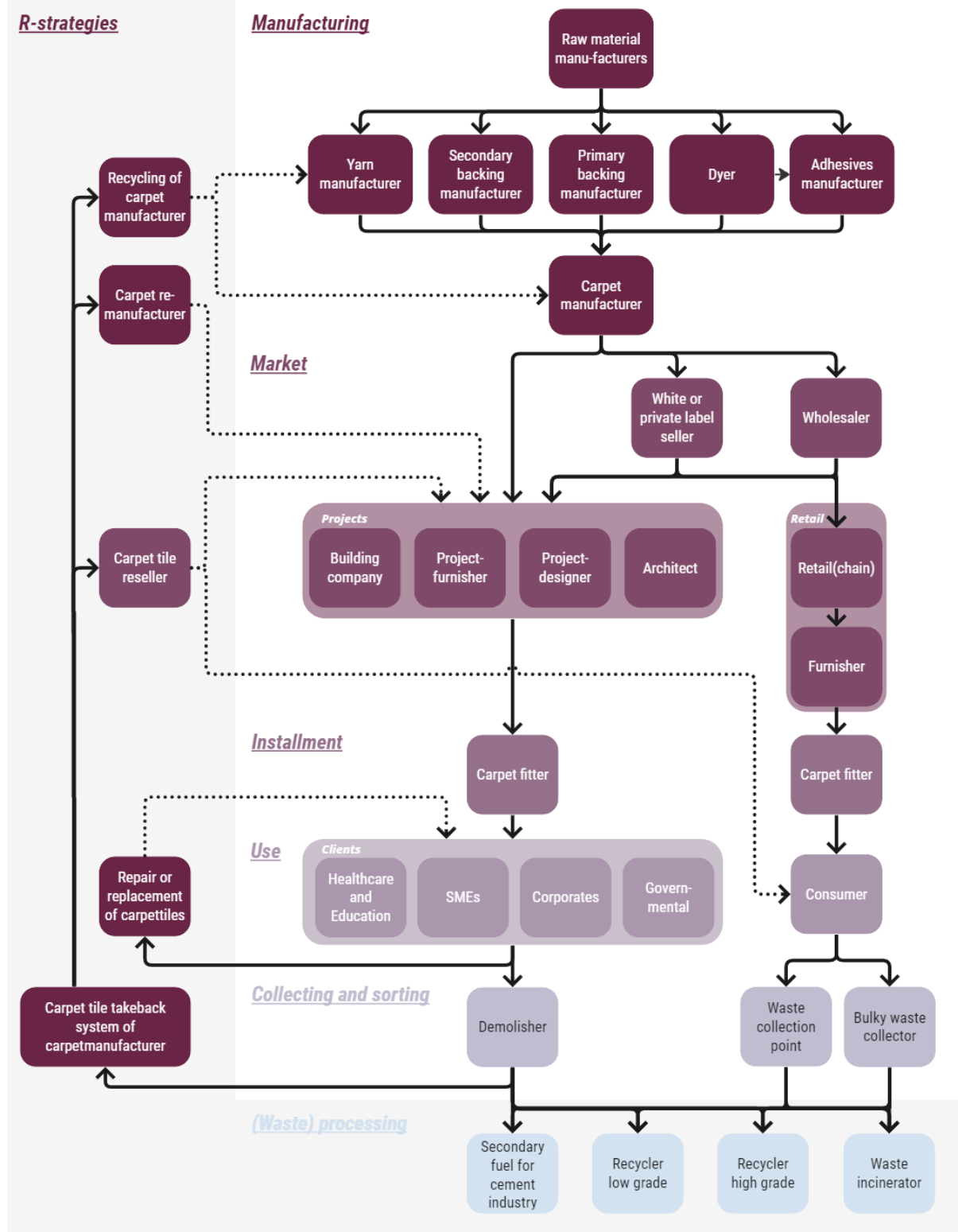
To understand the current landscape of circular strategies in the Dutch carpet industry, the actors, institutions, networks and infrastructure are discussed. This analysis shows the different actors involved with the adoption of circular strategies, assesses the institutional factors that encourage or hinder circular initiatives, and examines collaborative networks and infrastructure to understand the factors shaping sustainable practices in the Dutch carpet industry.

4.1.1. Actors

The Dutch carpet industry is one of the leading carpet industries worldwide (Behne, 2020; Woudt, 2021). To illustrate, Betap, a large carpet manufacturer, had a revenue of €140 million in 2019 (Woudt, 2021). Condor Group, a neighbouring carpet manufacturer, had a revenue of 427 million in the same year (Woudt, 2021). Last year Interface, known for their carpet tiles, had a revenue of 1200 million (*Interface Inc (TILE) Resultatenrekening - Investing.Com*, n.d.). Currently 85 companies are active in carpet production (*StatLine - Bedrijven; bedrijfstak*, n.d.). Most of these companies were founded over seventy years ago, making this industry an established industry. In 2021 the Netherlands exported over 200 million square meters of carpet with an export value of over 650 million euros (*StatLine - Goederen; grensoverschrijding, GN (8 digits, afdeling VIII-XV), landen*, 2023).

For the most part, carpet production takes place around the middle- and eastern regions of the Netherlands (Consultant). Figure 4 depicts the current carpet industry's supply chain. A cluster of carpet companies is located in the reformed Genemuiden where carpet production has been playing an important role for over a hundred years (Fix, 2018). Genemuiden's carpet cluster consists of one or more companies of each stage of the carpet's industry supply chain. Nowadays most of these companies are still family-owned making the lines of communication short. Genemuiden's carpet cluster is, directly and indirectly, providing an estimated employment of around 4000 people (Woudt, 2021). Carpet producers in Genemuiden are known for their big volumes, minimal production costs and hands-on, no-frills work ethic (*Het titanengevecht in de „tapijt”*, 2006).

Figure 4
Carpet industry supply chain

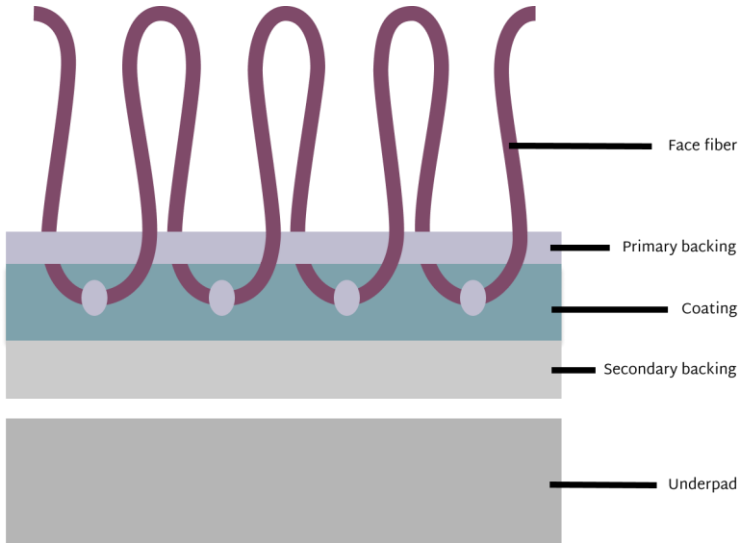


Note. The figure depicts the current supply chain of the Dutch carpet industry. Pilot projects are excluded. The movement of carpet products made from post-use carpet is illustrated by dotted lines. The supply chain is visualised based on interview data. Additionally, the data from (waste) processing are adapted from *Eindrapportage Moonshot Circulaire Vloerbedekking*, by S. Haffmans, F. Poppelaars and J. Vlugter, 2022, p.16 (<https://partnersforinnovation.com/nl/publications/moonshot-circulaire-vloerbedekking/>).

The production of carpet starts with the sourcing of materials by the carpet manufacturer. The industry shows examples of carpet manufacturers producing their own materials (i.e. yarn or backing). The level of vertical integration differs per carpet manufacturer. For example, large companies manufacture their own materials and control their supply chain up to the (waste) processing stage. This enables them to run a take-back scheme and produce carpet with recycled content.

For the most part, the carpet manufacturers produce tufted carpets in the form of tiles or wall-to-wall carpets. In 2021 tufted carpets made up almost 65% of the total exported carpet (*StatLine - Goederen; grensoverschrijding, GN (8 digits, afdeling VIII-XV), landen, 2023*). In the tufting process yarn is stitched through a primary backing material creating loops or cut piles and secured into place using adhesives. Secondary backing is added to provide stability. This can be made from a variety of materials, of which a bituminous backing is typically used in the European production of carpet tiles (*DESSO Carpet Rolls and Tiles - Tarkett / Tarkett, n.d.*). Figure 5 illustrates the structure of a standard carpet.

Figure 5
Typical structure of carpet



Note. Adapted from 2022-07 *TexAlert*, by A. Luiken & G. Brinks, 2022.

Carpet manufacturers either sell their carpet directly to clients or sell it to wholesaler, private label sellers or white label sellers. Private label sellers commission carpet manufactures to produce their carpet designs. White label sellers sell carpet produced by manufacturers with their own branding. The industry shows instances where all four parties sell to both the retail and project market.

The market stage of the Dutch carpet industry is split in retail and projects. Retailers sell directly to consumers. In projects the client could be a governmental organisation, a

corporate, a small and medium-sized enterprise (SME) or a healthcare or education provider. Oftentimes these projects are organised via a tender procedure. In projects the carpet manufacturer or carpet seller has contact with a group of actors that are involved in the project. The composition of the group differs per project, but oftentimes consist of an architect, project designer, project furnisher and a building company.

Mentioned by all interviewees, Van Dijk Containers is considered to be the main processor of used carpet in the Netherlands (Haffmans et al., 2022). The processing company is located in the carpet cluster of Genemuiden and is family owned.

4.1.2. Institutions

Carpet manufactured or sold in the Netherlands has to comply with several regulations with regard to safety, health and environment. This is outlined in the Construction Products Regulation (CPR) at the European level and in the Commodities Act at national level (*Commodities Act*, n.d.; *Construction Products Regulation (CPR) – European Commission*, n.d.). Both specify uniform guidelines for the marketing of (construction) products and define standards for the assessments of the performance of products. Harmonized standards are created by standardization bodies together with industry players and are established on national, European and international level (*Flexibele vloerbedekkingen en tapijten*, n.d.). Additionally, the CPR requires all indoor carpets to be CE-marked (*Construction Products Regulation (CPR) – European Commission*, n.d.). When a product bears the CE mark, it means that it satisfies the minimal standards for environmental, health, and safety outlined in the European directive for that particular product group (*Wetenswaardigheden over tapijten*, n.d.).

With the Dutch government's goal of a CE and the European Commission's circularity ambitions new legislation can be expected (Luiken et al., 2023b; *New Proposals to Make Sustainable Products the Norm*, 2022). At the moment only the Corporate Sustainability Reporting Directive (CSRD) is definite ('CSRD – Guide', 2023). The CSRD describes that large companies need to publicly report on their sustainability issues and strategies from 2024 onwards. From 2026 onwards SMEs are also required to report CSRD-compliant with simpler standards than large companies. For now, it only applies to companies which meet two out of the three following requirements: a net turnover of €40 million, €20 million on the balance sheet and 250 or more employees. Seeing as carpet manufacturing is highly automated it can be assumed that a high net turnover and balance sheet are the requirements relevant for this industry. This means that most of the Dutch carpet producers do not have to comply with this directive. However, since large clients of carpet producers will have to report on their sustainability issues and thus will require environmental data from their suppliers, carpet producers will have to start getting ready to disclose environmental product data.

Next to the CSRD, a relevant regulation with regard to circularity in the carpet industry is the possible upcoming Extended Producer Responsibility (EPR). An EPR is an environmental policy approach that extends a producer's responsibility for a product to the post-consumer stage and has been implemented in the Netherlands for product categories such as small household electronics and mattresses. In 2021 a study was carried out to investigate whether EPR is a suitable means of promoting the circularity of carpet and other floor coverings (Haffmans et al., 2021). Several actors within the system participated in this study. They prefer a voluntary EPR system, with leading parties who will take the initiative to give further effect to this transition, followed by a generally binding declaration. An important conclusion was that companies will need sufficient time to set up a system for recycling and collection, which is difficult due to the long lifetime of carpet.

4.1.3. Networks

In the context of the Dutch carpet industry, the examination of networks shows a multitude of different cooperative relationships and links between actors in the innovation system. Partnerships between manufacturers, suppliers and research institutions emerge as key drivers of progress. As mentioned in the theory section, these relationships can be formal or informal and may involve collaboration, knowledge exchange and resource sharing. By sharing knowledge and combining resources in for example initiatives like DSM-Niaga, the EPR study and the Moonshot project, stakeholders actively contribute to the adoption of sustainable practices. In particular, within the initiative Moonshot, initiated by the Versnellingshuis Nederland Circulair (Haffmans et al., 2022), industry alliances and partnerships are created which enables opportunities for joint research initiatives and joint problem solving. In partnership with Partners for Innovation, this initiative functions as a catalyst for change by broadening chains of collaboration, sharing knowledge and consolidating efforts with various stakeholders. One notable result is the creation of a shared roadmap, reflecting a collective commitment to achieve a circular carpet industry. By involving manufacturers, importers, construction companies, collectors, transport companies and waste processing companies, The Moonshot initiative highlights the shared responsibility for a circular transition.

4.1.4. Infrastructure

The physical infrastructure of importance for the implementation of circular strategies in the carpet industry includes machines to produce circular carpets, recycling plants and the infrastructure surrounding the collection of used carpet.

The industry shows examples of the using recycled content in carpet products, indicating that the infrastructure necessary to incorporate recycled materials in carpet products is in place. The Netherlands is home to two spinning mills specialised in creating yarn out of

recycled fibers (Luiken et al., 2023a). Large carpet manufacturers like Desso Tarkett and Interface (*Afvalstoffase Vloerbedekking / Bodemrichtlijn*, n.d.) are able to recycle carpet into yarn and backing. Additionally, these carpet producers provide the service of taking back the carpet waste that occurs during the installation of carpet in the project market. Hence, the infrastructure for reverse logistics is to some extent in place. Reverse logistics concerns the supply chain procedure of returning products from (end) users back to the producer or seller.

A range of infrastructure to support the collection and processing of used carpet is in place to support the implementation of circular strategies in the carpet industry. Currently three main methods are used for the collection of carpet after use. Consumers can dispose of their carpet via municipal waste collection points and municipal collection of bulky waste. In the project market containers are provided to collect the used carpet. This is collected by Van Dijk Containers for the majority of the project market (Haffmans et al., 2022).

At the moment, high quality recycling occurs mostly for carpet tiles and carpet from projects. However, the majority of carpet waste is incinerated and used as secondary fuel in cement kilns. Some finds useful applications in the automotive industry and as insulating material (Haffmans et al., 2022). The latter two are performed by Van Dijk Containers

Turning to the financial infrastructure, there are different financial mechanisms to support circularity in the carpet industry. These include subsidies, loans or investments. An overview of financing opportunities for research and innovation to support circularity in the carpet industry are provided in table 9. The connection to circularity is not always explicitly stated for example, subsidies for innovation could be used for circularity purposes.

Table 9
Financing opportunities for research and innovation

Regional	- EFRO / OP – Oost (subsidy percentage 40%-50%, max 2.000.000 euros per request)
National	- Circulaire Ketenprojecten (SMEs. Max 50K for a process supervisor)
European	- Horizon Europe - LIFE (subsidy 60-100% of the project costs, Budget 2021-2027 5.4 billion euros) - INTERREG (Vlaanderen – Nederland)
Investments	- ION+ OostNL (loans from 250-750 K, with a term of up to eight years, of which the first three years are redemption-free) - Topfonds Gelderland (SME loans) - MIA / Vamil en EIA (investments deduction) - Innovation credit (interest-bearing loan, up to 50% eligible costs) - InvestNL (investments in max 50% of the risk capital, 5 million – 50 million euros)

Note, reprinted from from *Eindrapportage Moonshot Circulaire Vloerbedekking*, by S. Haffmans, F. Poppelaars and J. Vlugter, 2022, p.16 (<https://partnersforinnovation.com/nl/publications/moonshot-circulaire-vloerbedekking/>).

4.2. System functions

This section focusses on the Dutch carpet industry's pursuit of circularity through seven system functions: entrepreneurial activities, knowledge development, knowledge diffusion, guidance of the search, market formation, resource mobilization and creation of legitimacy. Here, the research emphasizes the 'how' and is explored how the seven system functions shape the implementation of circular strategies and the industry dynamics. So, the mechanisms driving or hindering the Dutch carpet industry's journey towards circular practices are assessed.

4.2.1. Entrepreneurial activities

Societal pressure and the government's circularity goal are incentivising experimentation with circularity in the carpet industry. For the carpet industry, the three main areas where entrepreneurial activities could take place to steer the circular application of carpets are circular design, product circularity and circular business models. They are further elaborated upon below.

Circular design. One of the challenges for the carpet industry to start with recycling or reusing carpets, is that the current product stock is not designed with circularity in mind (Carpet producer 1, 2, 3, 4; Carpet remanufacturer; Policy advisor; Retailer). The majority of the current carpeting is involved with material complexity (combination of materials and adhesives and backings used which makes separation difficult) and design complexity (complex carpet designs and patterns can complicate the reuse). Embracing circularity therefore means reimagining the traditional manufacturing processes. This is shown by initiatives whereby designers focus on creating carpets with extended lifespans, employing modular designs that facilitate easy disassembly and repair.

Product circularity. Another dimension of circularity for carpets focuses on the end-of-life options. In table 10, an overview is given of the application of different R strategies mentioned by interviewees.

Table 10
Experimentation with R-strategies mentioned by interviewees

	Example of R-strategy in the Carpet Industry	Mentioned by:
<i>R0 Refuse</i>	-	
<i>R1 Rethink</i>	-	
<i>R2 Reduce</i>	Reducing the use of (primary) material in carpet tile production by using recycled content.	Carpet producer 1; Wholesaler; Retailer
	Reducing the use of (primary) material in yarn production by using recycled carpet or recycled fishing nets.	Label seller; Wholesaler

<i>R3 Re-use</i>	Offering used carpet tiles	Reused carpet retailer; project furnisher; carpet fitter; carpet producer 1
<i>R4 Repair</i>	-	
<i>R5 Refurbish</i>	Offering refurbished carpet	Label seller
<i>R6 Remanufacture</i>	Offering remanufactured carpet products	Retailer remanufacture
<i>R7 Repurpose</i>	Repurposing production cutoffs into product samples.	Carpet producer 2; 3
<i>R8 Recycle</i>	Enabling recycling by developing a polyester reversible glue that allows for the separation of materials in carpet in a collaboration between DSM and Niaga.	Carpet producer 1; 2; Label seller; Reused carpet retailer
	Mechanical recycling of carpet(tiles).	Project furnisher; label seller
	Chemical recycling of polyester based carpet.	Label seller; Carpet producer 3
	Development of a separation technology for the recycling of carpet.	Carpet producer 3
	Enabling more efficient recycling by developing a mono material carpet.	Carpet producer 1; Carpet producer 4; Label seller
	Enabling more efficient recycling by redesigning the carpet product to be easily separated.	Carpet producer 1; Consultant
<i>R9 Recover</i>	-	

Currently, the experimentation within CE strategy focuses mainly on recycling efforts (Carpet producer 3 & 4; Carpet remanufacturer; Consultant, Label seller). Carpet producers are exploring and experimenting with recycling in various degrees. New carpet products containing recycled content are currently commercially available, as well as carpet products that are designed to be recycled (e.g. mono material carpet or reversible glue). Additionally, mostly large firms are exploring the high-grade recycling of traditional carpet tiles and cutoffs². Most smaller carpet producers are not exploring high grade recycling, as this requires high investments (also for large firms).

² When installing carpet part of the carpet have to be cut off to make it fit.

There is a lack of actors that facilitate carpet recycling. Only one carpet recycler was mentioned by all interviewees who facilitates the logistics and incineration of the carpet. The residues of the incineration are used as reinforcement for the concrete industry.

Pilot studies within the carpet industry do serve compelling evidence that technical recycling is feasible, and that recycled content can be integrated into products without compromising quality compared to virgin materials (Carpet producer 1 & 4, Consultant). Notably, these initiatives demonstrate technical viability of the recycling process and the ability to maintain product quality standard. However, one challenge remains, namely the cost competitiveness of recycled materials. Despite that these pilot studies show a technical success, the economic value of recycled materials cannot compete with their virgin counterparts.

Next to recycling, some bigger firms are also experimenting with the reuse of carpet tiles. Modularity as described above in the circular design paragraph is mentioned as an enabler of the reuse of carpet tiles. The carpet tile reuse has gained interest in commercial office spaces, where flexibility and adaptability are often important indicators.

Circular business models. Next to design and end-of-life strategies, circular business models emerge as another pilot within the entrepreneurial activities of the Dutch carpet industry. Circular business models are deviating from the traditional linear approach. Circular business models can therefore drive systemic change in the industry's approach to production and consumption. Big firms are currently experimenting with reverse logistics, or take-back initiatives. This would allow customers to return their used carpet tiles at the end of their life cycle. These programs facilitate the collection of used products for further processing. It involves communicating benefits to their customers and an efficient sorting and processing, compliance and regulations.

Even though big companies are currently experimenting with take-back initiatives (Carpet producer 1 & 2, Carpet fitter, Consultant, Project furnisher) it is not present amongst other actors. Actors are unsure who will become responsible for the end of life of carpet. Specific plans on the implementation of circularity are currently not provided by the government, hence actors are not incentivized to experiment with reverse logistics. However, news on the government's interest of a possible EPR for the carpet industry has incentivised actors to provide new customers with their contact information (e.g. adding a label or QR code) to be able to facilitate a possible return. Producers do not feel rushed to experiment with reverse logistics, seeing as the lifespan of carpet is generally ten years.

There are also new entrants in the carpet industry who want and have integrated circularity to the core of their business. These startups are not merely driven by profit motives but are

driven by an intrinsic commitment to sustainability. These businesses can serve as an example for the broader industry.

4.2.2. Knowledge development

Knowledge development plays a pivotal role in advancing circular strategies within the Dutch carpet industry. Mostly from the perspective that knowledge is very much needed, but often missing. Out of the interviews, it became clear that knowledge can be looked at from different perspectives. It starts with basic general knowledge of the concept of circularity, then the ability to develop knowledge and lastly the practical knowledge for the execution of circularity strategies.

Knowledge base of circularity

All interviewed actors know that circularity involves the looping of materials and understand the need for circularity, but also mentioned this not to be something all carpet producers feel (Carpet producer 1, Carpet remanufacturer). The interviewees were familiar with all R-strategies, however not within the context of their framework (considering R0 (refuse) - R9 (recover), whereby R0 is the most preferable and R9 the least). A common perception amongst some interviewees is that a carpet product designed to be better recyclable equals a circular product. As carpet producer 1 mentioned: *'Basically, within the industry, the credo at present is: My product is recyclable.'* With this statement, the carpet producer wanted to illustrate a prevalent attitude in the industry where a recyclable product is viewed as sufficient in terms of circularity efforts.

Not only on the producing side of the carpet industry a lack of understanding of the concept of circularity was noticed, but also on the consumer side. For example, focusing on the project market, carpet producer 1 and label seller mentioned that a limited knowledge of circularity of the purchasing department of clients was present, whereby there was no additional value for the consumer when mentioned that a carpet had a 'circular' indication. This mostly revolves around costs, as circular carpets right now are more expensive than their regular counterpart. Carpet producer 1: *'We have a challenge when selling a carpet that is more circular, as the knowledge level of purchasers is zero, they get an assignment to find something [carpet] with a specific budget. So, there is not a lot of room to include the circularity dialog'*. Furthermore, besides the budget constraints, also time constraints were mentioned as an issue on the consumer side. Purchasers are often tasked with finding items urgently, and because of time constraints, the concept of circularity is not given the necessary attention, making it a challenge to convey the importance of choosing circular products and encouraging informed decision-making (carpet producer 1, label seller).

Development of knowledge

Besides the actual knowledge of circularity, it is critical that there is room for knowledge development itself. The government's plan to become circular in 2050, the anticipated EPR and the upcoming ESG reporting for large firms stimulates companies to start developing more knowledge surrounding sustainability and circularity. Knowledge development is mostly done by learning through experimentation, which is key in the industry. Due to the fear of losing their competitive advantage, the R&D of carpet producers happens in-house. This mainly applies to product innovations. Product innovations seem to revolve around carpet containing recycled content or better recyclable carpet, like carpet that is better separable at the end of use and a mono-material carpet enabling more efficient recycling. Current machines need to be adapted or new machines are developed to enable these product innovations. While carpet manufacturers can build on their knowledge gained from their many years of experience, experimentation is required to develop these products and machines. All interviewed carpet producers mentioned their involvement in the development or adaptation of machinery for recycling or the production of recyclable carpet products. It was mentioned that on the technical front, one machine is already well advanced, but that the actual commercialisation of the machine did not happen yet, so this is still behind closed doors. This development of knowledge is hampered by the high investment costs (of machinery) (Woudt, 2021). Label seller: *'Everyone is currently researching; everyone is in motion. However, a choice implies a significant investment. Each decision will entail a substantial investment, and it is possible to make a costly mistake'*. This implies that currently risk-averse behaviour is hampering further knowledge development.

Next to the knowledge development at the level of individual actors, knowledge is also being developed on the level of networks. This takes place in the form of collaborations between individual carpet manufacturers and Universities or businesses and research projects involving a range of stakeholders within the industry. An example of research projects in which knowledge development takes place is Moonshot. Within Moonshot, the recycler Van Dijk is involved in research on extracting polypropylene, enabling the carpet industry to reuse its own residual materials in production (Haffmans et al., 2022). Interviewed carpet producers 1,2, label seller and the carpet remanufacturer mentioned collaborating with universities (of Applied Sciences) in the development of new materials and recycling. The focus of these projects ranges from feasibility studies and sustainability assessments to material engineering. Another example is the CiSuFlo project. CiSuFlo aims to minimize environmental impact by establishing a systemic framework for circular and sustainable floor coverings, encompassing technical feasibility and socio-economic factors. Although collaborations between industry players are scarce, existing collaborations seem to have a big influence on the industry. Success stories are for example the collaboration between Aquafill and Desso Tarkett (collaboration in yarn innovation

enabling production of carpets with recycled content), and DSM and Niaga (collaboration in reverse glue innovation enabling the efficient separation of carpets).

Those collaborations like Moonshot and industry collaborations also provide industry-specific knowledge development to the government, which is necessary to formulate policy implementation for circularity. Nevertheless, interviewees still indicate the government's knowledge of the carpet industry to be lacking (Reused carpet retailer, Carpet producer 2 & 4). This could also be concluded based on several research reports on the textile industry. In these reports, the carpet industry is excluded from the scope, because reports are written either for the textile or flooring industry. This may sound like the carpet industry should be included, but the textile sector (in which the carpet sector belongs) includes other prominent segments like clothing, which has the focus of the government. In contrast, the flooring industry, with its focus on hard surfaces like linoleum and hardwood, excluding carpets. This is resulting in limited recognition in official government reports. This exclusion in government reports creates a knowledge gap within governmental bodies about the nuances of circular strategies for the carpet industry.

Practical knowledge for the execution of circular strategies

As discussed earlier, the primary focus within the carpet industry lies in recycling within the context of a CE. The interviews emphasized the importance of practical knowledge, particularly among contractors responsible for installing and removing carpets in buildings. One noteworthy aspect mentioned is the incorporation of QR-codes on carpets, containing essential information, in an effort to retrieve carpets at the end of their lifespan (Label seller).

During producer-contractor communication, it was revealed that carpets, crucial for potential reuse, had already been removed and shredded by personnel, rendering them unsuitable for recycling. Additionally, the QR code, intended to identify the producer, was unreadable due to the shredding process. The contractor emphasized that staff members are primarily focused on quickly extracting carpets, often neglecting attention to components that could facilitate reuse. They tend to follow established practices, aiming for efficiency in task completion. This highlights a lack of communication among various stakeholders, hindering knowledge development amongst workers who are crucial players in the collection and processing enabling recycling. The Moonshot project also highlighted the importance of collaboration and knowledge exchange between all entities involved, especially the workers in the field, because they are the first pillar in retrieving materials for recycling and reuse. They mentioned that the main bottleneck currently lies in the collection process, as carpets need to be collected separately and not combined with vinyl or other flooring materials. Reverse logistics, although not used in these terms, are therefore often mentioned in interviews, but lacks knowledge in actual execution.

The Moonshot program, in response to this barrier, aims to establish a nationwide collection system for installation waste and extend the lifespan of various types of floor coverings. Within their working groups, it was emphasized that there is a need for increased focus on lifespan extension, maintenance, and reuse.

4.2.3. Knowledge diffusion

Knowledge diffusion within the Dutch carpet industry faces challenges rooted in being a highly competitive and shrinking market. Knowledge is seen as competitive advantage and with concerns of losing this advantage now or in the future, this information is not shared amongst actors. Mostly because there is still a lack of knowledge in how circular strategies can exactly be applied to carpets, there is still a lot of freedom in finding solutions. With a lot of freedom in finding solutions, companies are very protective of their own innovations and unwilling to share this with others before commercialization. Carpet producer 3 mentioned: *' We signed a lot of Non-Disclosure Agreements, non-disclosure agreements. I have to, and I will, respect those. So, then I just can't say anything and also in terms of competition considerations, I'm not going to say everything. You have a lot of free-riders, also in this industry, I don't want to help them too much '.* This also shows that companies within the carpet sector are wary of sharing information because they are afraid their idea will be stolen. During the interview, Carpet producer 1 also mentioned that once an innovative idea emerges and hits the market, it is quickly copied. Knowledge diffusion, therefore, occurs mostly after all processes have been completed, and the innovation has been successfully implemented. Furthermore, the lack of knowledge diffusion is strengthened by the lack of government plans with regards to the implementation of circularity in the industry.

However, also examples of positive knowledge diffusion have taken place. In 2020 a study, issued by the government, was conducted to determine whether EPR is a viable strategy for encouraging the circularity of carpet and other floor coverings (Haffmans et al., 2021). This was followed up the next year by the Moonshot project in 2021 with its goal to accelerate the circular transition of floorcoverings (Haffmans et al., 2022). Within both projects stakeholders from within the SIS are gathered together by a consultancy firm to share and develop their knowledge together. Since the topic of the projects does not involve specific product innovations, participants are able to speak freely without compromising their competitive advantage. Remarkably, these projects, distinct from specific product innovations, provide a safe environment for participants to openly exchange insights without jeopardizing their competitive advantage. The absence of direct competition related discussions allows for a more and collaborative atmosphere. Another example of knowledge diffusion within research projects is the DSM-Niaga collaboration. Niaga had knowledge on carpet development, the industry and the ability to think freely, and DSM

added to this by providing knowledge on resources, technology and business, for example by providing guidance on patenting the product in all possible ways (van der Steen, 2017). Even though examples of knowledge diffusion in (research) projects are popping up, Carpet producer 3 mentioned: [regarding collaborations] *‘Yes, indeed, there is a growing trend. However, I do feel that people are keeping their cards close to their chest, very reluctant to share knowledge. But we're talking about this too. We can establish more collectively, and for scaling up nationally we're discussing it’*.

With respect to knowledge diffusion in the industry, the industry association Modint plays an active role in spreading information on recent developments with regards to circularity. For example, Modint’s newsletter TexAlert provides updates on the latest developments in the textiles industry, including developments relating to the carpet industry. Modint is not affected by competitive advantage, as it is an industry association. On a positive note, knowledge about carpet producers’ circular practices is here also communicated to customers through various channels. This includes the distribution brochures by Cunera, information available on the website by Donkersloot, and the dedication explaining an Environmental Product Declaration (EPD) to a customer by Interface.

4.2.4. Guidance of the search

After analysing the innovation dynamics within the Dutch carpet industry, it is revealed that notably shortcomings are present with respect to guidance mechanisms. This does not mean that there are no efforts employed by various stakeholders to direct innovation efforts toward specific circular strategy goals. The industry has mentioned that a shared goal is present within the industry, namely the implementation of sustainability and circularity. But besides mentioning this goal, the content and specific actions towards this goal remain unclear. Below, the main type of guiding initiatives are presented that try to work towards their shared goal.

Government initiatives and policy directives

In the context of this study the guidance of the search is influenced by the generic goal of the government to establish a circular economy by 2030. The overall goal of the government to implement more circularity in a variety of sectors is a driver for companies in the Dutch carpet sector to start identifying circular opportunities. However, as mentioned before in the knowledge paragraph, there is no industry specific information available by the government for implementing circularity. No specific guideline or roadmap is available, which results in a lack of guidance whereby opportunities remain on paper and are not further developed in concrete implementation. One of the interviewees mentioned: *“You do notice in the industry that people are getting nervous about the new legislation coming up, like UPV. They do want to act upon it and started for example with the QR codes. But mostly, the idea is that we still have 10 years to figure everything out so*

you can't call it a big pressure". The upcoming CSRD initiated by the European Commission has currently its biggest impact on larger companies, but SMEs will also be impacted because the larger companies are required to search for information downstream, for example with product passports. SMEs therefore have to supply information to larger companies regarding their products, which forces a start with CE implementation.

Even though government initiatives are present in the broader sense, sector specific initiatives are lacking. Carpet producer 1 mentioned that he had an idea of how the government could guide the sector in a more circular way, but that it is currently not present: *"Exactly, you could also consider it from a governmental perspective, much like a recycling center, for instance. Every supply stimulates demand, so if the government aims to promote carpet take-back through a recycling center, saying 'bring your products here', well, if we know that, we can also bring our products there and make the products more compatible for that purpose"*.

Pioneers

This brings us to the second type of guiding initiatives, pioneers. Within the industry, pioneers provide direction for circularity research. As previously mentioned in the context of knowledge diffusion, the introduction of a circular product by a pioneer creates confidence in other stakeholders within the carpet sector. Carpet producer 1: *"In the context of this study the guidance of the search is influenced by the generic goal of the government to establish a circular economy by 2030."* Retailer adds to this: *"And what you do notice is that when such a big name takes the initiative, you do see that other suppliers also, well, feel compelled to take steps."* This assurance stems from the understanding that the necessary research and testing phases have been meticulously navigated, thereby mitigating potential product shortcomings. For these stakeholders, witnessing a pioneer successfully bring a circular product to market serves as motivation for subsequent investments. Pioneers wield significant influence, as they can effectively guide the trajectory of research in the industry.

Academic research and education programs

A case study on the collaboration between DSM and Niaga has been described extensively in the scientific literature. The aim of this collaboration was to develop carpet materials that could be fully restored to their original shape in an economically feasible way without compromising quality. The technology specifically focused on pure polyester or polyester combined with wool or nylon, fused together with reversible adhesives to allow separation after use. This case study serves as a catalyst for the industry and offers opportunities to make carpets circular. However, apart from this case study, no other cases have been identified where academic research and educational programmes specifically address

carpet circularity, motivating the carpet industry to move further towards circular implementation.

4.2.5. Market formation

The market formation for circular carpets within the carpet industry reflects a complex landscape, whereby challenges are encountered with respect to the composition of the carpet market, export dynamics, and the promotion of circular products. The main principles of this function are presented based on market composition and niche markets.

Market composition

The market for carpet consists of a retail- and a project market and 85% gets exported. Both markets have been shrinking over the past few years (Fix, 2018). Interviewees mentioned upkeep, incompatibility with floor heating and interior trends to be its cause. The retail market of carpet is ageing, and younger people tend to opt for trendy hard flooring instead of carpet. Given that 85% of the carpets are exported, the international market plays a big role in shaping the trajectory of circular carpets. A focus on global acceptance and demand remains crucial for a functioning market formation. Although carpet producers try to promote their circular carpets, circularity is not a decisive reason to purchase circular carpets. Therefore, traditional carpets dominate the market, making it challenging for circular carpets to gain traction.

Niche markets

To give a clear description of potential niche markets within the Dutch carpet industry, we divide the retail- and project market. To start with the retail market, there is no specific identifiable niche market for circular carpets. Efforts to promote circular carpets encounter resistance as they must compete with an established, non-circular market in which prices are more favourable for traditional carpets and the quality is better. The label seller mentioned the quality of recycled material to be lower than traditional materials.

The project market on the other hand, shows more potential in developing a safe niche market to allow circular carpets to become more established. The project market demonstrates developments for refurbished and reusable carpet tiles. There seems to be an emerging demand in large-scale projects for substantial office spaces, especially in sizable projects and tenders for large office buildings. By having modular carpet tiles, has a benefit in these scenarios due to the easy removal and reuse. This aligns with the literature's emphasis on temporary niche markets (Hekkert et al., 2007). Flexibility in design and the ease of reinstallation align with the demand for adaptable work environments (retailer). However, even though an emerging niche market can be identified, in procurement processes of the project market low prices win. Interviewees mentioned purchase requests for carpet to give the impression that circularity is a decisive part, but that in the end

pricing almost always weighs heavier. It can thus be concluded that there is no strong foundation for a circular carpet market. Therefore, a circular carpet has to compete with traditional carpet which is very difficult to compete with not only on price, but also quality, as mentioned before.

Currently, not much profit is being made from carpet recycling (carpet producer 3, label seller). This can be seen in the current industry in the Netherlands, whereby van Dijk in Genemuiden is the only recycler present in the industry (Haffmans et al., 2022). Therefore, a monopoly position is present which makes market entry for new recyclers difficult. It can therefore be concluded that there is not enough demand for used carpet waste.

4.2.6. Resource mobilization

The long lifetime of carpet, the traditional industry and a shrinking market poses difficulties in the implementation of circular strategies within the industry. As carpet producer 3 mentioned: *"In a linear economic model at the big companies, you don't have time. Because if you don't get results in three years, you will be fired. Well, you won't get results in three years, you just won't."*

The capital intensity of the industry creates little room for error, inhibiting experimentation and knowledge development on circular strategies (Woudt, 2021). High grade recycling is very costly, even for large companies, and is not profitable (Carpet producer 3; van der Steen, 2017). Additionally, incineration is cheap (Vogels, 2019), not incentivizing recycling. Subsidies for recycling exist, but since actors do not know who will be responsible for recycling an incentive to act is missing. Adding to that, the subsidies present usually take a lot of effort and time to request for smaller companies. This is the same for larger companies, but due to more financial possibilities they usually outsource this task to consultancies (Carpet producer 1, Label seller). Large carpet producers offer a takeback scheme, although it does not turn a profit (Vogels, 2019). Smaller companies do not have the resources, money or (storage)space to set up reverse logistics. Also, to be able to process recycled materials as new input, machines have to be adjusted and due to a high pressure on creating a certain output per day, there is not sufficient room to replace machinery.

Another important factor in resource mobilization is the absence of concrete ideas on how to exactly become more circular. Lack of guidance impacts budgeting, as it needs to be known which processes need to be adjusted or developed in detail so related costs can be indicated. Therefore, no insight is specifically available of the total costs. Costs that are known and related to sustainability or circularity practices are for example EPDs, but the costs are most of the time too high for SMEs to give them a priority.

In the context of the resource mobilisation function, human capital emerges as a critical element for the successful implementation of circular initiatives. As highlighted in the previous knowledge chapters, the state of knowledge in the circular domain within the Dutch carpet industry is still in its infancy. This implies that, in terms of human capital, there is a shortage of individuals equipped with the expertise needed to lead large-scale circular projects. While there is a growing number of sustainability experts in general, specific focus on the carpet industry remains hard to find.

4.2.7. Creation of legitimacy

There is a general consensus on the need for circularity in the industry. However, the implementation of circular strategies is hindered by financial considerations, traditional mindsets, and resistance to change. Interviewees recognise that collaboration, supportive regulations, and an increase in awareness are essential in the industry's transition.

Although interviewees indicated that societal pressure creates legitimacy for circularity (Carpet Producer 3, Label seller, Project furnisher), circularity is generally not a decisive element in the purchase of carpet (Carpet producer 1, Carpet remanufacturer, Carpet fitter). In the project market a growing number of companies are interested in circular carpet (Carpet producer 2; Vogels, 2019), in part because of their image. However, in procurement processes, lower prices more than often still win (Carpet Producer 1, Carpet remanufacturer).

Recycling is seen as the most legitimate option of all r-strategies (Carpet producer 3, Consultant). This is due to that recycling has been introduced into the carpet industry way before the other r-strategies. Therefore, this is a more mature innovation compared to other r-strategies: technical knowledge regarding product development, waste treatment and reverse logistics have already been developed, shared and put into practice.

Legitimacy for the implementation of r-strategies is increased significantly when established companies put these in practice. It has been seen that the whole industry views the implementation of recycling as less of a risk, due to that established carpet manufacturers have already included recycling in their business as usual (Carpet producer 3, Retailer).

Since a small number of actors has developed business models where the use of reuse and remanufacture have been commercialised, the legitimacy of actors within the industry towards these strategies is increasing. This is because the commercialisation of business models including these r-strategies serves as a proof of principle for the industry.

As stated before, the carpet industry is a more conservative industry that is reluctant to big changes due to the risk combined with these changes (Label seller, carpet remanufacturer). This mindset is a barrier in making the changes required for the circular transition. Actors within the industry state that specifically managerial support for circular changes is an important factor in the shaping of the mindset throughout the industry.

Reverse logistics of exported carpet is hampered by waste legislation (Carpet producer 1, 3, 4). Since used carpet is classified as waste, regulations hamper the transport over borders (*Questions and Answers on New EU Rules on Waste Shipments*, n.d.).

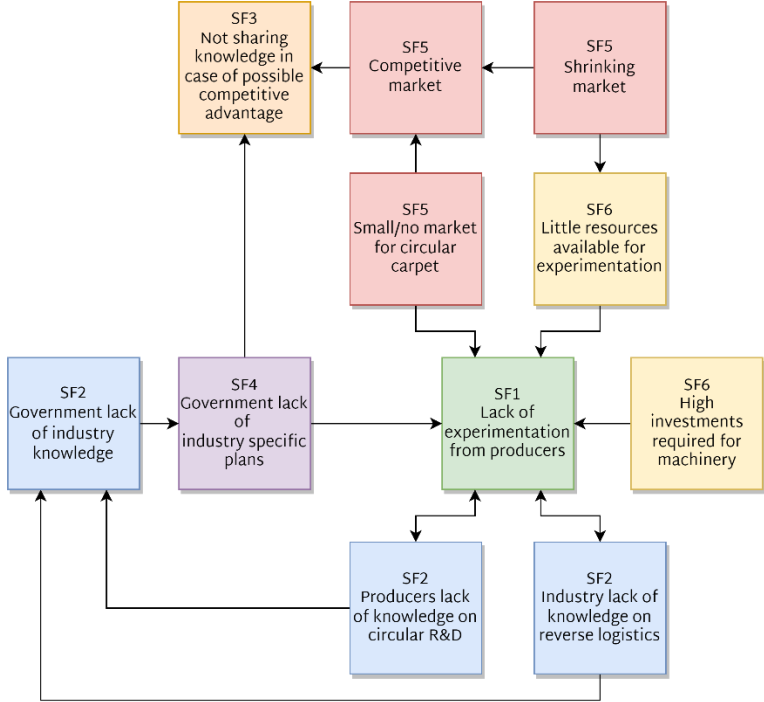
4.3. Interdependence of drivers and barriers

Following the structural-functional analysis of the Dutch carpet’s industry efforts on implementing circular strategies drivers and barrier are identified. The following section focusses on the interdependencies between these drivers and barriers. Two sets of interconnected barriers and one set of interconnected drivers were identified.

4.3.1. Interdependencies between barriers

The first set of barriers identified show multiple interdependencies regarding the experimentation of carpet producers. This first set of interdependencies between barriers is visualised in figure 6.

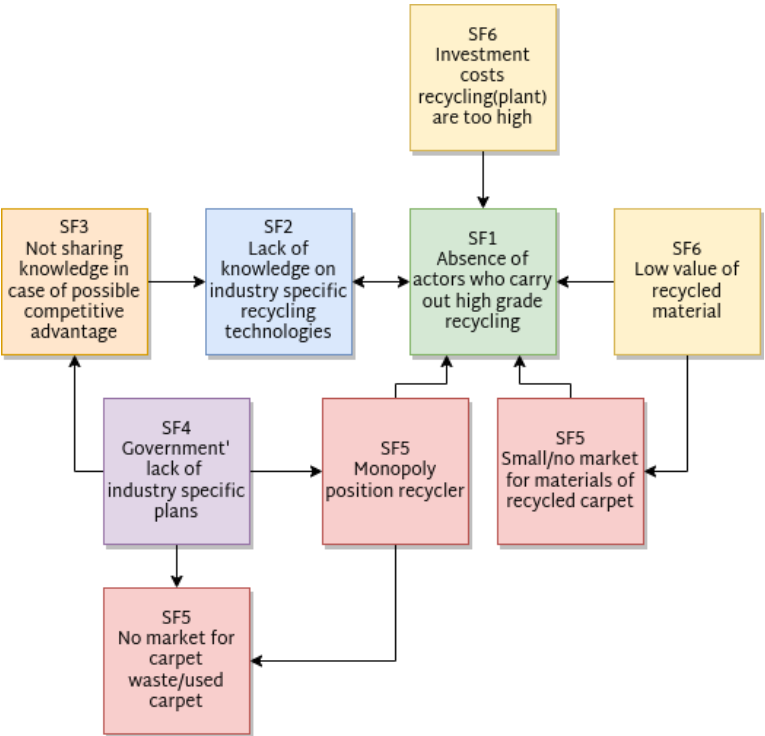
Figure 6
Interdependencies of barriers around the experimentation of carpet producers



There is a lack of knowledge dissemination due to the competitive and shrinking market for carpet, and relatively no market for circular carpet. Actors are reluctant in sharing information regarding innovation, since this could compromise their competitive advantage. This reluctance in sharing knowledge is further strengthened by the government's lack of industry specific plans. With the future direction unknown all information lead to a potential competitive advantage. This lack of guidance and the high investment costs associated with machinery inhibit the experimentation of carpet producers. This lack of experimentation hampers the industry's knowledge development of R&D on circular strategies and reverse logistics. The industry is therefore not sufficiently able to provide the government with industry specific knowledge which is necessary to create plans for the industry.

The second set of barriers revolve around recycling and show similarities with the first set of barriers with regards to guidance of the search and knowledge dissemination. This second set of barriers is visualised in figure 7.

Figure 7
Barriers 2



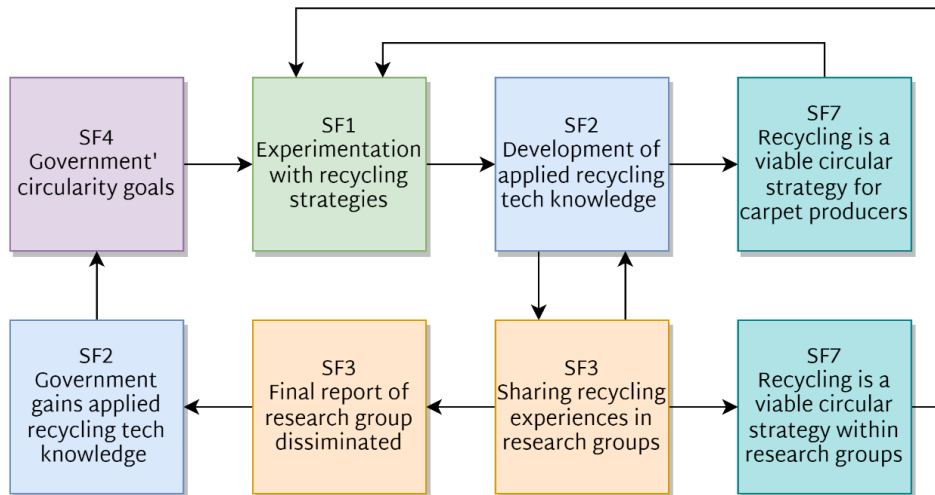
At the moment the risks and costs associated with implementing circular strategies as a carpet producer would not result in a return on investment, since there is virtually no market for circular carpet. Meaning, that currently circular carpet has to compete with non-circular carpet. This poses difficulties regarding price. Additionally, the carpet market

is highly competitive regarding price, further strengthening the reluctance in knowledge sharing.

4.3.1. Interdependencies between drivers

Next to interdependencies between barriers, interdependencies between drivers were identified. The interdependencies between drivers are visualised in figure 8.

Figure 8
Interdependencies between drivers



The little guidance from the government that has already been defined (circularity goals 2030–2050 and possible EPR) have already resulted in increasing performance of the innovation system. Although the defined plan stumbles upon a lot of resistance by actors within the industry, because they realise they have to change their ways. This does instigate a wave of entrepreneurial activity, knowledge development, knowledge dissemination and creation of legitimacy.

The possibility of the introduction EPR has resulted in established firms developing knowledge and experimenting with reverse logistics, which is necessary to enable circular strategies. Legitimacy for the implementation of r-strategies amongst the whole industry is created when established companies implement these strategies. This increase makes the change towards this r-strategy seem less risky for smaller businesses.

There has been an increase of networks and the increase of use of existing networks for the circular transition. In these networks competitive consideration are removed as much as possible, resulting in a huge increase of knowledge development and knowledge dissemination. Knowledge is shared for as much as they are allowed, due to Non-Disclosure Agreements (NDA).

5. Discussion

The Dutch carpet industry is a large industry that is required by the Dutch Government to make the circular transition. Even though a complex product like carpet is known for its difficulties with a circular transition, little is known on the current state of circularity of the industry and policy to guide this transition is lacking. Because of this lack of knowledge and policy regarding this industry, the aim of this research was to describe how the implementation of circular strategies can be stimulated in the industry. This was done by first describing the current state of the implementation of circular strategies in the industry, and from that identifying drivers and barriers around the implementation of circular strategies in the industry. The insights from this study provide the industry and government knowledge on how to stimulate the circular transition of this industry.

5.1. Theoretical contribution

This study expands the limited literature available on circularity in carpet, and contributes to IS literature highlighting the importance of analysing drivers and demonstrating the interdependencies between drivers and barriers.

First, this study expands the existing body of literature regarding the circular transition of the carpet industry by providing insight into the current status of circular strategies in the industry. Current literature indicates the carpet industry to be at the beginning of its circular transition and to be focussing on lower-level circular strategies (Howard et al., 2022; Velter et al., 2020). This study confirms the focus of the industry to be on the lower level r-strategies. However, several instances also show the application of the higher level r-strategy reduce and the combination of both. This is in line with the studies of Reike et al. (2018) and Morsetto (2020) noting that lower-level R-strategies can be combined with others to achieve a greater total circularity.

Second, this study highlights the importance of analysing drivers and demonstrates the interdependencies between drivers and barriers, thereby contributing to IS literature. Barriers are more favourable in literature from a policy standpoint (Nevzorova & Karakaya, 2020). This study illustrates the value of drivers. When solely looking at the barriers identified in this study, limited knowledge of higher-level r-strategies and reverse logistics would lead to the conclusion that the knowledge development of actors is lacking. However, when also taking drivers into account the knowledge development in research groups shows promising progress in the development of the SIS.

As discussed in theory established industries are known for the interconnections between system components (Bergek et al., 2008; Kieft et al., 2017). This research has shown that this is similarly true for the Dutch carpet industry. Upon analysing the SIS around the implementation of circular strategies in this industry this research has found several instances of barriers and drivers strengthening each other. Building on the notion of

Hekkert et al. (2007) regarding possibility of modifying the innovation process due to the identification of drivers and barriers, the findings of this research suggest that nourishing an interconnected driver or barrier could create a ripple effect stimulating further development of the mature SIS.

5.2. Practical implications

The results of this study provide guidance for practical application for carpet companies and other actors. There seems to be a particular need for action for the government, as this research shows that policy is one of the deciding factors for companies to invest in circularity.

This study finds that the Government's plans regarding the circular transition of the Dutch carpet industry is too unclear. Hence, system actors are limited in their circularity decisions, as this can result in unnecessary investment and losses. Due to the competitive market, actors are reluctant to share their knowledge. In order to accelerate the circular transition within this industry and to ensure that CE strategy implementation is stimulated, government institutions need to provide more detail on the guidance in the circular transition within the carpet industry. This research has shown that there is a great willingness to implement circular strategies, but that actors are hindered by several factors.

5.3. Limitations of the research

Although several measures, described in the methods section, have been taken to ensure the quality of this research this research has its limitations. First, with regards to data collection the high competitiveness of the industry resulted limited information on the latest innovations within the industry. Although this effect has been limited as much as possible by ensuring anonymity for participants.

Second, the dynamic nature of IS poses difficulties in the generalisability of this study. This study aimed to provide an overview of the current situation of the industry and although it provided this, this is a snapshot of this moment.

5. Conclusion

This study aimed to investigate how the implementation of circular strategies can be stimulated in the Dutch carpet industry. To do so, the current state of the use of circular strategies, and the drivers and barriers in the implementation of circular strategies within the Dutch carpet industry were investigated. This study aimed to fill in the research gap in current literature by going beyond the end of life of carpets, focussing on the implementation of circular initiatives and taking a systems perspective to analyse the Dutch carpet industry to identify the drivers and barriers in the circular transition of this industry. This study used a literature review and qualitative research conducted among industry stakeholders of the carpet industry. Results show that to stimulate the CE implementation, it is recommended that a mix of barriers need to be overcome and enablers should be implemented.

First, key barriers that need to be overcome are a lack of knowledge dissemination due to the competitive market, the risk-cost aspect, lack of resource mobilisation, and the lack of clarity of policy. The results show that the lack of knowledge dissemination is due to the competitive market as actors within do not want to share new information regarding innovation as this could compromise their competitive advantage. Another barrier that was identified was related to the risks and costs involved. Stakeholders conveyed that implementing circular strategies as a carpet producer would currently not provide a return on investment, since there is no market for circular carpet and the carpet is highly competitive regarding the price. Adding onto this risk-cost aspect, a lack of resource mobilisation was found to be a barrier. This is explained by the high costs associated with implementing and experimenting with circular strategies within an industry in which on the key indicators of performance is efficiency – which has been optimized within this industry for the last 50 years. Lack of clarity on government policy was found to be another barrier. A push from outside of the market is needed to overcome negative attitudes towards making investments and sharing information regarding CE strategies. The government is the only actor outside of the market, yet stakeholders are unsure if the current policies will apply to them. As these policies shape the implementation of their circular transition, actors are hesitant of making a high investment for a circular innovation, because they might have to alter that investment later.

Key drivers are guidance from the government, and the exemplary role of established companies within the industry. This supported by the already increasing performance of the IS since the government defined circularity goals for 2050 and possible EPR. Although the defined plan stumbles upon resistance by actors within the industry, it also instigates a wave of entrepreneurial activity, knowledge development, knowledge dissemination and creation of legitimacy. This is showcased by established firms developing knowledge and

experiment with reverse logistics, and actors engaging in entrepreneurial activity regarding reuse and remanufacturing of carpets. Furthermore, there has been an increase of networks and the increase of use of existing networks for the circular transition. Additionally, established names within the industry may have an exemplary role in the implementation of r-strategies among the whole industry. When established companies include recycling in their business as usual, this reduces the perceived risk of implementing this r-strategy for smaller businesses.

By having identified the key barriers and drivers in the innovation system of the carpet industry, this study contributes to the further development of circular transition in a systemic way, whereby all stakeholders were given a voice. Future research should focus on investigating how these barriers work together, to further provide value for the industry.

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Appendix A – Interviewguide, in Dutch

Stap 1: vertrouwelijkheidsverklaring

“Hallo mijn naam is Manon Diemeer. Ik ben momenteel bezig met mijn scriptie voor de master Sustainable Business & Innovation aan de universiteit Utrecht. In mijn onderzoek probeer ik te achterhalen hoe de implementatie van circulaire strategieën in de Nederlandse tapijtindustrie gestimuleerd kan worden.

Deelname aan dit interview is vrijwillig en u kunt het interview op elk gegeven moment stoppen. Voor we beginnen wil ik u ervan verzekeren dat alles wat u vandaag zegt vertrouwelijk en anoniem zal zijn, dus niets van wat u vandaag zegt met uw naam geciteerd zal worden. Ik zal vertrouwelijk met de data omgaan, in lijn met AVG wetgeving, en het alleen gebruiken voor mijn scriptieonderzoek. Ik wil graag bevestigen of ik uw toestemming heb om dit interview op te nemen, zodat ik het kan transcriberen? Heeft u verder nog vragen over de vertrouwelijkheid van dit interview?”

Stap 2: Het systeem, en de structurele componenten

Introductie geven over circulariteit. Vragen of ze bekend zijn met de R-ladder. Wanneer actoren niet bekend zijn met r-strategieën in de vragen focussen op circulariteit in plaats van de strategieën.

	Vragen
Op het niveau van het bedrijf of organisatie	<ul style="list-style-type: none">- Zou u uzelf kunnen voorstellen en kunnen toelichten wat u rol is binnen <i>naam bedrijf</i>?- Wat is uw rol betreffende circulariteit binnen <i>naam bedrijf</i>?- Hoe lang bent u hier al mee bezig?- Wat is de aanpak w.b. r-strategieën binnen <i>naam bedrijf</i> en wat is hiervoor de motivatie?<ul style="list-style-type: none">o Vragen naar concrete voorbeelden om daadwerkelijke acties te achterhalen
Op het niveau van het systeem	<ul style="list-style-type: none">- Hoe ziet de waardeketen van tapijt er uit in Nederland?- Wie zijn de belangrijkste actoren/partners waar <i>naam bedrijf</i> mee samenwerkt?<ul style="list-style-type: none">o en betreffende r-strategieën?- Hoe ziet zo'n samenwerking er uit en hoeveel (constante) afstemming is er nodig om r-strategieën waar te maken?- Kunt u actoren benoemen die partners van u bedrijf zijn in toepassen van r-strategieën in productontwikkeling?

Stap 3: Functioneren van innovatiesysteem

Introductie geven over innovatiesystemen:

“Mijn onderzoek kijkt vanuit een **innovatiesysteem** perspectief naar de **circulaire transitie** van de **Nederlandse tapijtindustrie**. De hypothese hierbij is dat individuele actoren ondersteund of belemmerd worden door het innovatiesysteem waar zij onderdeel van zijn. Een innovatiesysteem bestaat uit een **netwerk van actoren** die betrokken zijn bij een innovatietraject, in dit geval

circulariteit. Samen bepalen zij in grote mate de **snelheid en richting van het innovatieproces**. De **institutionele structuur** bepaald hierbij sterk wat de actoren **willen, kunnen en mogen**. Als een innovatiesysteem goed functioneert dan leidt dit tot **veel innovatieve activiteit en snelle diffusie van de innovaties**. In een matig functionerend innovatiesysteem wordt innovatie belemmerd. De mate van functioneren van het innovatiesysteem kan worden bepaald aan de hand van **sleutelfactoren**, de zogenoemde **functies** van het innovatiesysteem. Deze functies betreffen: het experimenteren door ondernemers, kennisontwikkeling- en verspreiding, of er genoeg richting wordt gegeven aan het zoekproces, marktcreatie, het mobiliseren van middelen, en legitimiteit creëren.”

Na afloop van elke systeemfunctie vragen de persoon het te laten beoordelen, wanneer dit niet kan zoveel mogelijk een indicatie vragen.

System functies	Vragen
Experimenteren van ondernemers	<ul style="list-style-type: none"> - Wordt er binnen de industrie veel geëxperimenteerd met circulariteit? Pilots etc. - Zie je ondernemers met nieuwe oplossingen w.b. r-strategieën de markt binnentreden? Of zie je juist ondernemers de markt verlaten? - In welk stadium van ontwikkeling zie je dat deze oplossingen zijn? Wordt er al opgeschaald? Blijft het bij prototypes? Of zijn het alleen gesubsidieerde projecten?
Kennisontwikkeling	<ul style="list-style-type: none"> - Hoe zou u het huidige niveau van kennis over r-strategieën (en circulariteit) in de industrie evalueren? Hierbij doel ik zowel op beschikbaarheid als kwaliteit - Zou u aan kunnen geven in hoeverre de huidige staat van kennis voor een belemmering zorgt in een succesvolle transitie van uw bedrijf?
Kennis verspreiding	<ul style="list-style-type: none"> - Hoe wordt er kennis verspreid over r-strategieën en circulariteit binnen de industrie? - Zijn er veel samenwerkingsverbanden? Tussen wat voor actoren? - Wordt er kennis gedeeld onderling, tussen tapijtfabrikanten? <ul style="list-style-type: none"> o Zie je hier problemen in?
Richting geven aan het zoekproces	<ul style="list-style-type: none"> - Is er een duidelijke visie binnen de industrie over r-strategieën en circulariteit? <ul style="list-style-type: none"> o Verschild dat per bedrijf of is daar een algemeen beeld over? o Welke rol speelt de overheid hier in? o Is er wet- en regelgeving, beleid of normen die hier op aansluiten? Of mist dat? - Hoe zou u de visie van uw organisatie classificeren in r-strategieën? - Wat zijn de verwachtingen van r-strategieën?
Marktcreatie	<ul style="list-style-type: none"> - Is er vraag vanuit de markt naar circulair tapijt? - Zijn partners binnen de industrie actief bezig met het creëren van bewustzijn over r-strategieën en circulariteit bij consumenten? - Denk je dat er genoeg wordt geïnvesteerd in de implementatie van r-strategieën en circulariteit binnen de industrie? - Biedt de overheid hulp met het creëren van een markt voor circulair tapijt?

	<ul style="list-style-type: none"> ○ Wat mist je hierbij nog? - Wat is volgens jou daarnaast nog nodig om de markt verder te ontwikkelen?
Mobiliseren van middelen	<ul style="list-style-type: none"> - Is er genoeg financieel kapitaal en menselijk kapitaal beschikbaar voor de implementatie van r-strategieën in de tapijtindustrie? - Waar gaat het kapitaal voor de implementatie van r-strategieën en circulariteit nu het meest naar toe? Onderzoek, implementatie, pilot projecten etc.? - Zijn er specifieke fysieke middelen die de implementatie van r-strategieën tegen gaat?
Tegengaan van weerstand en legitimiteit creëren	<ul style="list-style-type: none"> - Waar is er weerstand zichtbaar tegen de implementatie van circulaire strategieën? (bestaande regelgeving, normen, bedrijfsbelangen binnen de waardeketen, gebrek aan bewustzijn) - Wat wordt er aan gedaan om dit te overwinnen en legitimiteit te vergroten? <ul style="list-style-type: none"> ○ Rol overheid? - Denk je dat er veel macht is om te lobbyen bij actoren in het systeem?

Stap 3: Afsluiting

- Is er iets wat we nog niet besproken hebben en wat u graag wilt toevoegen?
- Wie of welke organisaties denkt u dat relevant is voor mij om te interviewen?
- Kan ik na dit interview nog contact met u opnemen voor onduidelijkheden of verdere vragen?
- Bedankt voor uw deelname aan mijn onderzoek. Zou u geïnteresseerd zijn in het ontvangen van mijn uiteindelijke scriptie/onderzoek?