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Summary

As the climate crisis looms in, governments have responded with several agreements to lower their carbon emissions and decouple their economic growth from the fossil industry. This transition to a cleaner economy has spurred innovations in several dimensions to find green alternatives to the depleting resources. The Dutch government has then adopted the circular economy model and set ambitious goals to reach full circularity by 2050, which promotes the exploration for bio alternatives as substitute for non-renewables. Therefore, systemic changes are required in sociotechnical systems to allow radical innovation to shift to a bioeconomy and disassociate the current system from the fossil industry. To realize this, new value chains were created across the lifecycle of products and new networks were built to unite different agents across industries. While this transition is characterized by complexity and uncertainty, a single agent cannot take the risk of breaking away from the business as usual and adopt an innovative model. As a result, regional networks were created as in the Circular Biobased Delta in South Holland, which implemented the triple-helix model to steer biobased innovations. This regional cooperation combines local governments, provinces, industries, and knowledge institutions across the region and beyond working on providing a protective space for biobased innovations that reduces the carbon emissions. Regardless of these ambitious targets and established ecosystem, the ongoing government effort in transiting to bioeconomy were considered locked in a predevelopment stage and, characterized by vested interests from top-sector companies to slowdown radical changes and maintain a locked-in economy. These intrinsic features of the Dutch economy can be ascribed to several factors that affect the development of biobased innovation.

This research aims at empirically explaining the impact of the factors affecting the development of biobased innovation within the Circular Biobased Delta on the Dutch bioeconomy transition. By making use of Transition Management, and Strategic Niche Management theories, it attempts to explore the applicability of this framework on small-scale innovations led by entrepreneurs for the bioeconomy transition. For this reason, one innovative material aiming at creating radical changes in the asphalt industry and developed within the CBBD was selected as the case study. Lignin-based asphalt or Bioasphalt is an innovative technology seeking to displace the bitumen-based binders in asphalt with the bio binder, lignin.

Accordingly, the research strategy is designed as a deductive case study by identifying the factors through the MLP-SNM literature as a theoretical framework to guide and map the empirical factors. Eleven interviews with key actors in the case study (Bioasphalt) network were conducted to collect the required data related to these factors, their plans and strategies for developing the technology, their interdependencies along with the relationships they have established, and their motivations. Secondary data was also used to triangulate the findings while coding the data with Atlas.ti to analyze and filter the information.

Theoretically, the analysis has confirmed the applicability of the MLP-SNM framework for use in understanding the factors affecting the development of biobased niche innovation and the impact on the bioeconomy, albeit its shortcomings. These weaknesses in the framework stem from its intrinsic static features and inability to examine the dynamics of the innovation process. For this reason, making use of the transition broker literature assisted in forming a sufficient analysis of the case study, while adding quantitative indicators like the

Technological Readiness Level may also improve the assessment of phase changes in this framework.

Furthermore, the findings sided with the literature criticizing the slow development of the Dutch bioeconomy ascribed to eleven factors affecting the biobased innovation development. The urgency factor in the Dutch circular economy plans, and the environmental assessment indicators are among the factors that are negatively affecting the biobased innovation and derailing its development. Other nine factors are also identified in this research that, when taken into consideration can assist not only policymakers but also actors in the bioeconomy to accelerate the development of radical innovation.

On a macro level, a clear definition and positioning of the bioeconomy in the Dutch Circular Economy strategy along with integral implementation plans may further endorse biobased innovation. While on micro level, creating a robust and broad network around the innovation with specific goals and shared vision will allow for its rapid market penetration.

Keywords

Transition Management, Bioeconomy, Innovation, Sustainability, Bioasphalt.

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Abbreviations

AKC	Asfalt Kennis Centrum (Asphalt Knowledge Center)
BBD	Biobased Delta, Foundation
CBBD	Circular Biobased Delta, Foundation
CE	Circular Economy
EZK	Ministerie van Economische Zaken en Klimaat (Ministry of Economic Affairs and Climate Policy)
II	Innovatiegericht Inkopen (Innovation-oriented Procurement)
LCA	Life Cycle Assessment
MKI	Milieu Kosten Indicator (Environmental Cost Indicator)
MLP	Multilayer Perspective on Sociotechnical Transitions
MVI	Maatschappelijk Verantwoord Inkopen (Socially Responsible Procurement, Corporate Social Responsibility)
PBL	Planbureau voor de Leefomgeving (Netherlands Environmental Assessment Agency)
RVO	Rijksdienst voor Ondernemend Nederland (Netherlands Enterprise Agency)
RWS	Rijkswaterstaat (The Dutch Ministry of Infrastructure and Water Management)
SNM	Strategic Niche Management
ST	Sociotechnical
TIS	Technological Innovation Systems
TKI	Topconsortia voor Kennis en Innovatie (Top sectors for Knowledge and Innovation)

TM	Transition Management
TNO	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (Netherlands Organization for Applied Scientific Research)
TRL	Technology Readiness Level
UU	Utrecht University
VITO	Vlaamse Instelling voor Technologisch Onderzoek (Flemish Intitute for Technological Research)
WUR	Wageningen University – Food and Biobased Research

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Chapter 1: Introduction

1.1. Background and Problem Statement

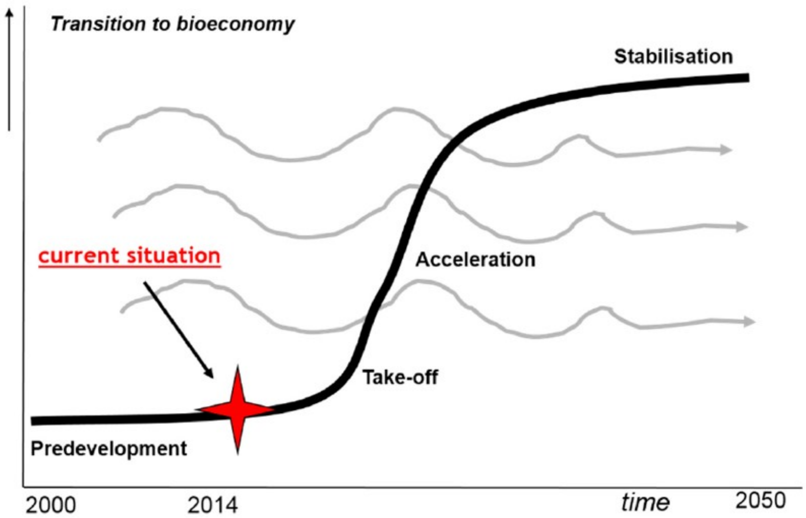
The current climate emergency requires serious measures by governments to take actions before this looming crisis. The overconsumption of natural resources, along with reliance on fossil industries, have contributed to global warming, accelerated the depletion of natural resources, and increased the amount of waste. While governments have adopted the Sustainable Development Goals to avoid climate and social crises, bioeconomy has emerged as a new model of economy that directly contributes to several of these goals. Although there is no consensus on the definition of bioeconomy, it is generally accepted that it implies the use of biomass, biotechnology and biomaterials for sustainable production to decouple the economy from fossil industries and preserve the natural resources (De Besi and McCormick, 2015, Mills, 2015). The involvement of multidisciplinary science and technologies, along with the integration between urban and rural areas for biobased production to achieve circularity, are what presents the bioeconomy as an alluring opportunity for governments to shift away from the linear production models (Pfau; Hagens, et al., 2014). This shift from fossil dependency to bioeconomy is termed as the Bioeconomy Transition (Hermans, 2018).

Nevertheless, this transition is characterized by the interdependency and multidisciplinary cooperation adhering to the difficulty of management due to implications from uncertainty, long-term frameworks, extensive networks, and high cost that accompanies the process. Therefore, the transition management will require networking, experimenting, and interaction between several actors of different scales, interests, and domains (Loorbach, 2010, Hermans, 2018). This complex transition means there is a need for multi-layers of innovation away from the business as usual model; from policies and strategies applied on the macro-level sociotechnical systems' landscape, down to the micro level of niche innovation with the latter creating a pressure on the conventional technologies to make a radical change (Shove and Walker, 2007). A popular explanation is that the empowerment of the niche innovation is an impetus for the required radical changes in the incumbent regime to enforce this transition (Bosman and Rotmans, 2016, Tani, 2018).

While the bioeconomy is largely dependent on the natural resources, each country prioritizes its transition management strategies depending on its sectors and subsectors in accordance with the available natural resources. For this reason, the Netherlands is developing its bioeconomy around its top-sectors namely, chemistry, energy, and agriculture as it lacks the vital natural resources like forests or agriculture land large enough for other sectors like both biomass and food production (Bosman and Rotmans, 2016, Bracco; Calicioglu, et al., 2018, TKI, 2015).

During the last decade, the Dutch government has taken steady steps to shift to sustainable growth and reduce the exploitation of its natural resources. The kingdom efforts were manifested in national and international agreements and deals that obliged the government to take serious measures in decoupling its economy from the fossil industry and shift to circularity and biobased economy (EC, 2019, IPW, 2016, EC, 2014, BZK, 2017) laying the seeds for new opportunities in a circular economy with biobased production being at its heart. Structured policies, roadmaps, and support schemes (LNV, 2007, Langeveld; Meesters, et al., 2016, IPW and EZK, 2013, Taakgroep Innovatie, 2019) were introduced to setup an encouraging environment for innovation, while focusing on regional networks and facilitating both top-down and bottom-up solutions to bioeconomy transition (Bosman and Rotmans, 2016). Accordingly, the national government steered biobased economy innovation through cooperation between top industrial sectors and niche innovators (Jansen, 2019). These transition management techniques served as an innovation highway in top sectors with focus on the energy and chemistry sectors to restructure their incumbent regimes. On the other hand, the absence of an integrated innovation policy regarding biobased products remains an obstacle to the development of an economic green model (Rijksoverheid, 2019, Taakgroep Innovatie, 2019).

Figure 1: Dutch transition to bioeconomy



Assessment of the Dutch bioeconomy transition according to Bosman and Rotmans (2016).

Regardless of these ambitious targets and established ecosystem, the ongoing government effort were criticized in the literature. The Environmental Assessment Agency (PBL) labelled the transition process in the Netherlands as lagging behind and in the predevelopment stage (Hanemaaijer; Manders, et al., 2014). Meanwhile on the European level, an analysis of the Bioeconomy Strategies (Overbeek; Bakker, et al., 2016) has revealed specific issues with the transition setup on regional levels in the Netherlands. Some of which are the lack of networking for niche innovation, lack of shared vision, and portrayed the transition as slow. Additionally, Bosman and Rotmans (2016) sided with the previous reports adding a warning from biased policies towards 'vested interests' by top-sectors while the transition goal is too ambitious (Figure 1).

On the other hand, the above evaluation of the bioeconomy transition in the Netherlands was based on the multi-phase framework, which Rotmans already criticized in his earlier literature. According to Grin; Rotmans, et al. (2010) this framework lacks phase-change thresholds and systemic changes indicators, as well as the empirical grounds for the four phases, which opens a gap in the literature leaving the evaluation of the bioeconomy transition with no normative indicators and up to the assessment of the evaluator.

Meanwhile, the national government has facilitated the creation of regional clusters to strengthen innovation and create suitable environments to incubate niche innovation under the larger players of the network, namely the 'vested interest sectors'. Simultaneously, those top-sectors (i.e. energy, chemistry, and agriculture) worked with the government to strengthen their position and weather the bioeconomy wave by having an exclusive access to niche innovation to avoid a radical change (Bosman and Rotmans, 2016, Overbeek; Bakker, et al., 2016).

On a different level, local governments and municipalities play a significant role in stimulating bottom-up innovation for being part of the regional clusters and close to niche innovation; hence, they have the potential to accelerate the transition towards bioeconomy. However, they lack the critical mass to act solely to steer innovation (Cramer, 2020a). Similar to regional smart specialization and circular economy transition, the ecosystem required for steering innovation does not necessarily exist within the same city but through regional collaboration (Lovrić; Lovrić, et al., 2020, Carayannis; Grigoroudis, et al., 2018, Rijksoverheid, 2019). Such setup gives a unique characterization to the bioeconomy transition due to the interactions within the transition arena requiring the interdependence between municipalities, provinces, national government, knowledge institutions, society, and industries *(quadruple helix)* that may not share the same regulations, policies, or goals and culture. As the case in the Circular Bio-Based Delta (CBBD) in the south of the Netherlands, the network has crossed borders to include actors from both neighboring countries.

The CBBD is a registered foundation that has several programs to support biobased innovation focusing on chemistry and agriculture with to lower the carbon emissions in the region. One of these programs is the CHAPLIN Program, which is dedicated to the outplacing of bitumen in the asphalt mix with its biological rival lignin. As governments are the main customer due to their ownership of the majority of roads, this Bioasphalt innovation is still seeking demonstrations on road sections with several governmental levels to test and develop the technology. However, this shift in the asphalt industry is dependent on several factors contributing to the evolution of this biotechnology transition.

1.2. Research objectives

This research aims to empirically explaining the impact of the factors affecting the development of biobased innovation within the Circular Biobased Delta on the Dutch bioeconomy transition. While the MLP-SNM theoretical framework was used predominantly to analyze the transition in top sectors and large-scale sociotechnical systems like mobility or energy, this research attempts to explore the applicability of the same framework on small-scale innovations led by entrepreneurs for the bioeconomy transition in the Netherlands.

Therefore, an investigation of the transition management is provided in the following chapter followed by mapping of the factors influencing the development of biobased niche innovation. Secondly, a deeper evaluation of the interactions between lignin-based asphalt actors in the CBBD as a case study will allow for the identification of the relationships between the factors affecting biobased innovation within this region and the impact on the incumbent regime shifts. Finally, analyzing these factors in order to understand their stimulation and stagnation powers on the innovation development, and the bioeconomy transition, respectively.

1.3. Main research question and sub-questions

To achieve the above goal, the main question for this research is:

Which sociotechnical system factors explain the development of biobased niche innovation in the asphalt industry, and how do these factors affect the regime shifts in the Dutch bioeconomy transition?

To answer the main research question, the following sub questions are required:

- How does the sociotechnical system influence the development of biobased niche innovation in the asphalt industry?
- What explains the incumbent sociotechnical regime shifts in the bioeconomy context?
- To what extent the transition management in the asphalt industry affects niche innovation in the Dutch bioeconomy context?

Therefore, the research investigates which factors stem from the three levels of the sociotechnical system that slow or prevent –to some extent- the development of radical innovation, as well as the factors inside the CBBD network (niche). The impact of these factors on innovation and the interaction between them should therefore explain the incumbent regime shifts towards the bioeconomy transition.

1.4. Significance of this research

The Dutch government response to the climate crisis is to create pressure on the fossil-dependent industries to adopt a circular economy model, which will allow for the bioeconomy transition. However, this pressure has been unable to accelerate the transition, and a revaluation of the current roles and interdependencies between actors in the transition arena is urgently required in order to meet the Dutch transition management interim goals of 2030. Moreover, the process of developing new technologies is dependent on several factors and unpredictable, meanwhile limited literature is available for assessing the impact of the factors affecting the development of biobased innovation in the bioeconomy context, such empirical knowledge will spur changes within the sphere of niche innovation management that should resonate in the bioeconomy transitions literature. Therefore, the applicability of MLP-SNM framework on small-scale innovations like the Bioasphalt may contribute to the development of niche biotechnologies in general, and Bioasphalt in specific to allow for its rapid deployment on the Dutch roads, which will contribute to the development of the Dutch bioeconomy.

1.5. Scope and limitation

As the bioeconomy transition is on a regional level, this research focuses on asphalt innovation within the Circular Biobased Delta region in the Netherlands. According to Overbeek et al. (2016), this regional cluster is one of the fastest developing biobased regions in the Netherlands, and most of its biobased products resulted from niche innovation. Therefore, this research seeks depth not breadth by targeting the factors existent in the three levels of the sociotechnical system, which affect the development of radical innovation in the asphalt industry along with the internal nurturing processes. Therefore, the research does not question the policies made by the Dutch government rather the focus is limited to mapping the situation in the region, and practices used by the actors across the value chain to nurture innovation as well as the limitations to its development. This excludes questioning the strategies used by the agents, the decision-making processes inside the business firms regardless of their scale, and the effect of the factors on the institutional and organizational interaction within these firms. Although the impact of the nurturing processes of the niche can affect the regime in several ways, the scope is limited to the pressure force that the niche can pose on the regime which is manifested in the 'signs' of regime shifts, and does not extend to the governance of the network or the innovation ecosystem from the TIS perspective.

Chapter 2: Literature review

2.1. Biobased economy transition

As the threat of climate change is becoming imminent in many cities around the world, the need for shifting towards sustainable economies appear as a dominant solution for governments. Circular economy being at the heart of these new models of economy, it focuses on nonlinearity of materials, and reducing the use of non-renewable resources. The bioeconomy, or biobased as the Dutch call it, fits well in this approach for involving the use of renewable resources, and the production of biomaterials that reduce the impact on the environment. While the consensus for the definition of biobased economy has not been reached (Bugge; Hansen, et al., 2016, De Besi and McCormick, 2015, Wydra, 2020), several countries have adopted the European Union's definition with minor alteration depending on its local resources and industries (Bracco; Calicioglu, et al., 2018). Regardless of which, the most common concepts in the biobased economy definitions involve the exploitation of materials from renewable bio-sources, the use of biotechnology, value-added production, and involvement of several industry sectors customized at country or region level (Bugge; Hansen, et al., 2016, Vanhamaki; Medkova, et al., 2019, Birner, 2018). In this research, the most relevant definition for the case study is the one that Bosman and Rotmans (2016) have used in their evaluation of the Dutch bioeconomy, which they adopted from the Dutch government definition of bioeconomy as "… *A highly developed bioeconomy uses green resources firstly in the production of food and feed and only afterwards or simultaneously in the case of waste products for chemicals, materials, and energy. (Referring to the biomass value pyramid)"*

Therefore, in order to focus on the transformation of the economy from fossil-based to bio-based, a reconfiguration of sociotechnical systems is required to comprehend the mechanisms behind this transformation. From the policy and social perspective, there are four main theories that are relevant to transition management and innovation for sustainability namely; Transition Management (TM), Strategic Niche Management (SNM), Multilevel Perspective on Socio-technical Transitions (MLP), and Technical Innovation Systems (TIS) (Markard; Raven, et al., 2012). However, the focus of this research is on the first three theories for the relevancy of the case.

2.2. Transition Management

Complexity and governance are central to the concept of transition management. The term transition implies a state of fundamental morphological changes to a system, while the management stresses on the possibility of shaping this process of changes for a desired trajectory. Due to the uncertainties, complexity, and long-term requirements that are typically associated with system transformations, the transition management concept is widely used in the transition of sociotechnical systems towards sustainable path-independent systems (Loorbach, 2010). Consequently, the transition discussed in this research is on the level of sociotechnical systems, meaning a change of system from a state of to another. Several transition management theories are focusing on influencing the interactions between the institutions, society, and technology in order to create radical societal changes and control its subsystems (Hölscher; Wittmayer, et al., 2018).

Loorbach and Rotmans (2010) address sustainability governance in the definition of transition management as meta-governance and "… *a deliberative process to influence governance* *activities in such a way that they lead to accelerated change directed towards sustainability ambitions."*

This translates into a level of complex interplay of developments between technological, economic, socio-cultural, and institutional systems (Loorbach, 2007). These developments require multiple involvement of different actors in networks with a high level of interdependency, cooperation on multi-level focus, and social learning (Loorbach and van Raak, 2006). Accordingly, it is characterized by a shift in the societal system or subsystem from one dynamic equilibrium to a new dynamic equilibrium state. However, the progress of this process is at erratic pace and requires innovation in different parts of the system entailing structural changes (Kemp and Loorbach, 2003).

2.2.1. Multilevel framework

To explore and explain the factors affecting niche innovation in the above transition process, the multilevel theory is the most common framework used to structure the sociotechnical systems and analyze its mechanisms (Wihlborg; Sörensen, et al., 2019, Hoogma; Kemp, et al., 2002, Markard and Truffer, 2008). Based on Hoogma; Kemp, et al. (2002) and developed later by Geels (2005), the levels of this framework are the macro, meso, and micro as shown in (Figure 2).

The focus of this research is on the micro-level manifested in the Niche due to being the protection space for emerging innovations, with the latter flourishing on the social networks built inside this level. Niche also provides the learning processes that empower innovation for new solutions that are fundamentally different from the regime up to the point of creating radical systemic changes and threatening the whole sociotechnical system (Wihlborg; Sörensen, et al., 2019, Markard and Truffer, 2008). Two types of niche exist based on the macro level; the market niche which has different criteria from the regime (meso level); and the technological one which is created by investments from public or private institutions (Geels, 2005, Hoogma; Kemp, et al., 2002).

On a different scale, the most impactful is the Meso level or in other words the Regime, which includes the social relationships, institutions, and technology. The strength of this level is derived from its contribution to the functionality of the whole system and its responsibility for stabilizing the system (Wihlborg; Sörensen, et al., 2019, de Haan and Rotmans, 2011).

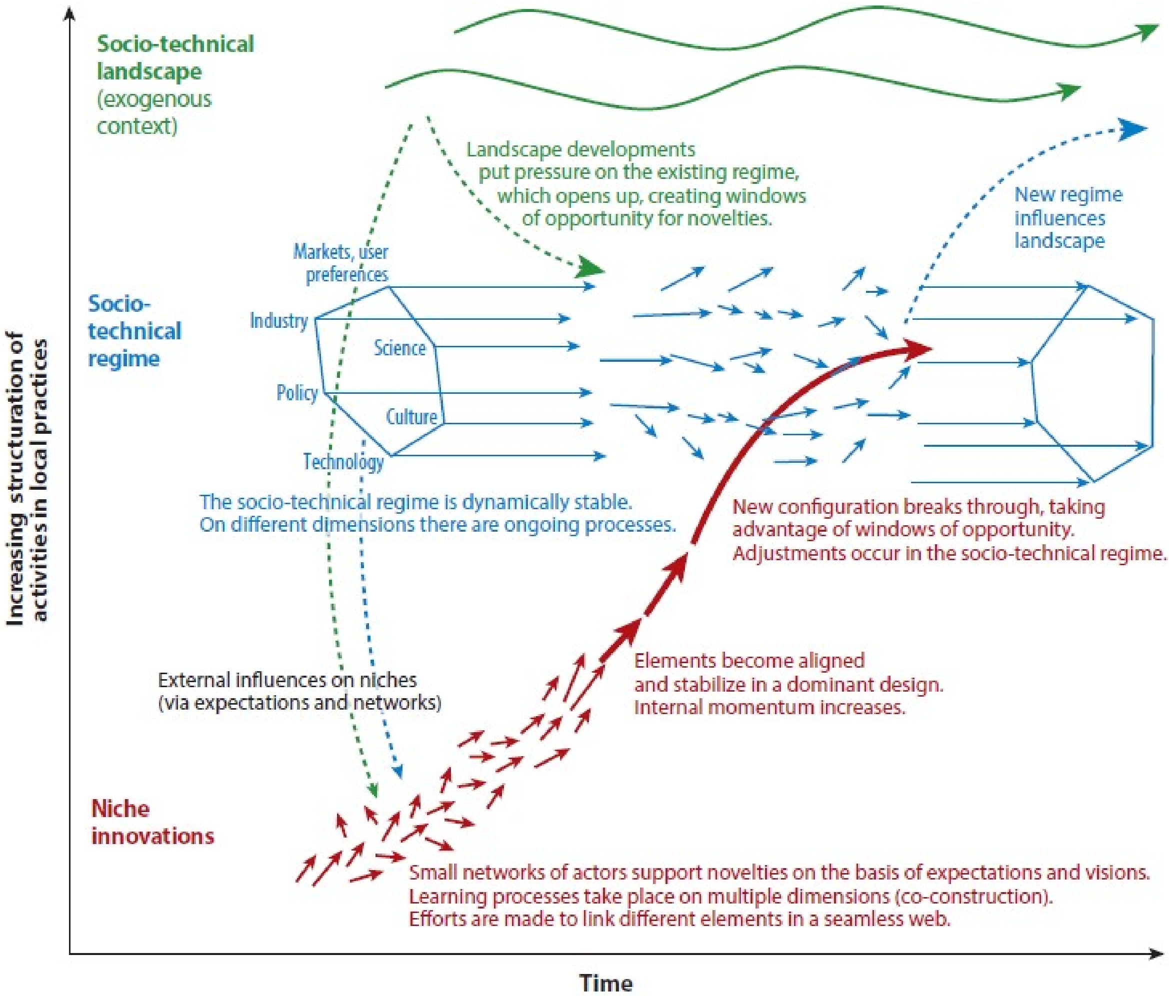
Being the Macro level, the Landscape is the context where the other two levels operate. This landscape influences the development of both other levels on the long-term as it includes the legal system, the demography, economy, and natural environment. This power manifests itself in being the '*selection environment*' for technological development fueled by the intrinsic functions of its components (de Haan and Rotmans, 2011, Markard and Truffer, 2008, Geels, 2005).

2.2.2. Multilevel dynamics of economy transition

The dynamics of sociotechnical system changes rely on the interactions and interdependencies between its subsystems. These interactions result in *tension, stress, and pressure* powers that flow between the system's components, compromising its functioning or *raison d'être* ensuing systemic changes. These forces are positive and negative externalities that give rise to niche innovation to replace the regime through the open windows they create for transformations.

As shown in (Figure 2Figure 3), due to the dependence of the regime on the landscape for the flow of materials, tensions appear in different dimensions; structural and cultural. The former type of tension appears in the physical aspects of the system (i.e. infrastructure, legal system, or economy) while the cultural tension would refer to conflicts in cognitive, or ideological aspects. Examples of this tension between the regime and landscape or niche and landscape can materialize in pollution, debates, protests, or changes in public opinion. The stress comes from within the regime for its incompetence to fulfil its functioning. The mismatch between the cultural and structural rules in the regime is the main driver of this force, a good example for this is creating subsidy programs to reduce the gap between production and shortage leading to overproduction. The third force, pressure on the regime comes about from the competitive alternatives to its functioning like the appearance of new technologies that outperform the incumbent. This pressure typically originates in the niche level against the regime (de Haan and Rotmans, 2011).

Figure 2: Dynamics of the sociotechnical system transition



Sociotechnical system multilevel framework and its dynamics (Loorbach; Frantzeskaki, et al., 2017).

2.2.3. Multiphase framework

While the transition management process involves generational changes and nonlinearity, it is typically a gradual process of four phases depending on the size, direction, and speed of the transition. This multi-phase framework has been used as an assessment method by several academics to evaluate the development of transition management in different countries (Bosman and Rotmans, 2016, Kemp; van Asselt, et al., 2001, Kemp and Loorbach, 2003) albeit the lack of threshold values, indicators for the shifts between each phase, and more empirical evidences (Grin; Rotmans, et al., 2010). The four phases of this multiphase framework are:

1. Predevelopment phase is the least developed state of transition involving myriad experimentations, but with little visible changes on the societal regime.

2. Take off phase follows on when some changes to the system occur, and a paradigm shift starts to surface.

3. Breakthrough/Acceleration phase comes in as structural transformations become visible through the accumulation of interdependent interactions of several system components.

4. Stabilization phase is the final transition phase when the system reaches a new dynamic equilibrium state and the pace of societal changes slows down.

While the process is characterized by perturbations, major events like wars, pandemics, or natural catastrophes can accelerate this process but not drive it. Kemp and Loorbach (2003) refer to the transition development as an outcome of the interactions between internal and external changes on social, cultural and technical levels, which renders multiple causalities.

2.3. The transition Brokers (intermediaries)

The MLP framework is commonly used when analyzing green transitions or the interactions between niche innovations aiming at creating a sustainable shift (Smith; Voß, et al., 2010, Gliedt; Hoicka, et al., 2018). Fischer and Newig (2016), and Cramer (2020a) stress on the role of agency or actors in the transition and how they can orchestrate the governance of innovation to shape the transition trajectory. They have exposed the inadequacies of the MLP for inattention to the agencies (actors) and focusing mainly on the structure (system), posing a challenge for innovation to exploit the windows of opportunity to scale up and change the regime (Wittmayer; Avelino, et al., 2017).

Obviously, the transition management requires major systemic changes and creating pressure from the macro-level through the formation of new policies and regulations where the governments play a major role in managing this process. At the same time, innovations are dependent on the market willingness to adapt to new technologies (Fischer and Newig, 2016, Cramer, 2020b), and this is where the challenge lies for new market comers (innovation) to collaborate with the government (agent) and force the systemic changes. Therefore, the use of intermediaries in the transition process is not only logical but also inevitable to bridge the gap between the agents and create links between the ecosystem's substructures (Fischer and Newig, 2016, Rauschmayer; Bauler, et al., 2015). Accordingly, the recognized key actors are niche actors, regime actors, and intermediaries. The intermediaries, or *the Transition Brokers*, act as boundary spanners for innovations through disseminating information, creating partnerships, and mediating between the triple (or quadruple) helix actors on regional levels (Gliedt; Hoicka, et al., 2018, Cramer, 2020b, Fischer and Newig, 2016). By the same token, five types of intermediaries were identified according to Kivimaa; Boon, et al. (2019); the process, the user, the regime-based, the niche-based, and the systemic intermediary.

As the MLP explains more the system dynamics, it provides the basis for understanding how the actors can influence these dynamics thus, transition governance is how actors can influence the transition processes (dynamics). Consequently, transition government represents the way actors organize themselves, mainly through social networking, to create solutions for changing the sociotechnical regime and generate resources for that same reason (Loorbach; Frantzeskaki, et al., 2017).

2.4. Niche Innovation

As path-dependency is one of the main features of the sociotechnical systems, they are always reluctant to changes. These lock-in inherent characteristics are often the barrier for divergent innovations that challenge the stability of the incumbent regime. Therefore, these innovations lack enough '*competitive advantages*' to create radical changes and they need more intensive support than what they usually receive based on their expected performance (van der Laak; Raven, et al., 2007). Here is when the niche space interferes, where the local innovations develop in a safe ecosystem away from the rigorous regime rules, and landscape selection characteristics. Hoogma et al. (2002) define this space as "*a discrete application domain (habitat) where actors are prepared to work with specific functionalities, accept such teething problems as higher costs, and are willing to invest in improvements of new technology and the development of new markets.*" This means that the development of the niche is dependent on the relationship between the niche and the other system levels, mainly the regime. While the macro-level represents the selection environment, the regime will eventually play another selection role to choose the compatible innovations in order to prevent its own failure and diminish radical innovations, or realign these innovations with the regime locked-in trajectory (Smith, 2003).

2.4.1. Strategic Niche Management (SNM)

Based on Evolutionary Economy, the Strategic Niche Management theory (SNM) was developed during the last two decades of the twentieth century, ultimately to explain the management of two types of innovation. The first is social innovation with long-term transition goals as sustainable development and, the second is related to radical innovation that is barred by the other components of the sociotechnical system (Schot and Geels, 2008).

SNM as a policy focuses on the technology policy to promote experimentations before market niche developments as the main driver for the creation and development of new technologies. Strategic Niche Management theory is then based on two fundamental assumptions; the first is related to the co-evolutionary nature of the emerging technologies as a social process. The second assumption relies on experiments in niches for targeted technologies and markets, which increases knowledge processes required by the innovation and facilitates the adoption of these new technologies (Hoogma; Kemp, et al., 2002). Schot and Geels (2008) revealed other assumptions; mainly sustainability innovations are radically different, and the selection environments (regime and landscape) are inhomogeneous and made up of a variety of niches.

Kemp et al. (1998) define strategic niche management as "*the creation, development and controlled phase-out of protected spaces for the development and use of promising technologies by means of experimentation, with the aim of (1) learning about the desirability of the new technology and (2) enhancing the further development and the rate of application of the new technology.*"

2.4.1.1. Protection Space

Smith and Raven (2012) stressed on the establishment of protection space for the creation and development of innovation, specifically radical innovation. The importance of such spaces is based on the disability of innovations to create path-breaking forces if they were part of the incumbent regime. In a similar sense, Bosman and Rotmans (2014) warned of *vested* *interests* and their impact on the incubated innovations in the socio-technical regimes ensuing incremental innovation and stagnating the radical transformation of the regime hence the need for a protective space away from the selection pressures of the regime.

Owing to their initial low performance and expensive characteristics, radical innovations are in need of these protection spaces in their initial development however, remaining in a cocoon for a long period may cause more harm than benefit for such path-breaking *hopeful monstrosities* (Geels, 2002).

2.4.2. Factors Affecting Niche Innovation

The factors affecting the development of niche innovation are interrelated, and interdependent. Factors can be barriers that influence the innovation process in a negative way; their absence is a driver to innovation while the absence of the drivers is a barrier as well. These factors can also interchange their functional impact depending on the stage of innovation development. In this research, the word 'factors' refer to both the drivers and barriers to niche innovation. The taxonomy of these factors is based on the source from where these factors originated. This classification is reflected from empirical studies of innovation firms regardless of their size in the niche space and can be defined as endogenous (i.e. organizational culture, resources) or exogenous (i.e. environmental resources, economy, regulation) factors (Hadjimanolis, 2003).

By supporting radical sustainable innovations in order to compete in the niche market and replace the incumbent regime, SNM conceptualizes a set of processes in order to create an eminent change. As shown in (Figure 3), these bottom-up processes start with the emergence of new technologies then they establish dominance in the niche market, and finally replace the incumbent regime. For a successful realization of this process, three internal niche processes must be analyzed which are 1) the alignment of expectations between actors, 2) establishing a robust social network, and 3) quality learning process. (Looijenga, 2020, Schot and Geels, 2008, van der Laak; Raven, et al., 2007).

2.4.2.1. Convergence of expectations

Actors in the network for niche development including policymakers, entrepreneurs, and industries take part in the new technology experimentation projects based on their own vision and expectations out of these projects. Shaping this vision and aligning expectations allow for the allocation of different types of resources to increase the success factors. At the same time, it gives directions to the design process of these technologies resulting in more protection and nurturing mechanisms (Schot and Geels, 2008). This means that the bigger the number of actors sharing the same expectations, the higher likelihood of their success, and to align more actors on the same expectations will require tangible results from these projects (van der Laak; Raven, et al., 2007).

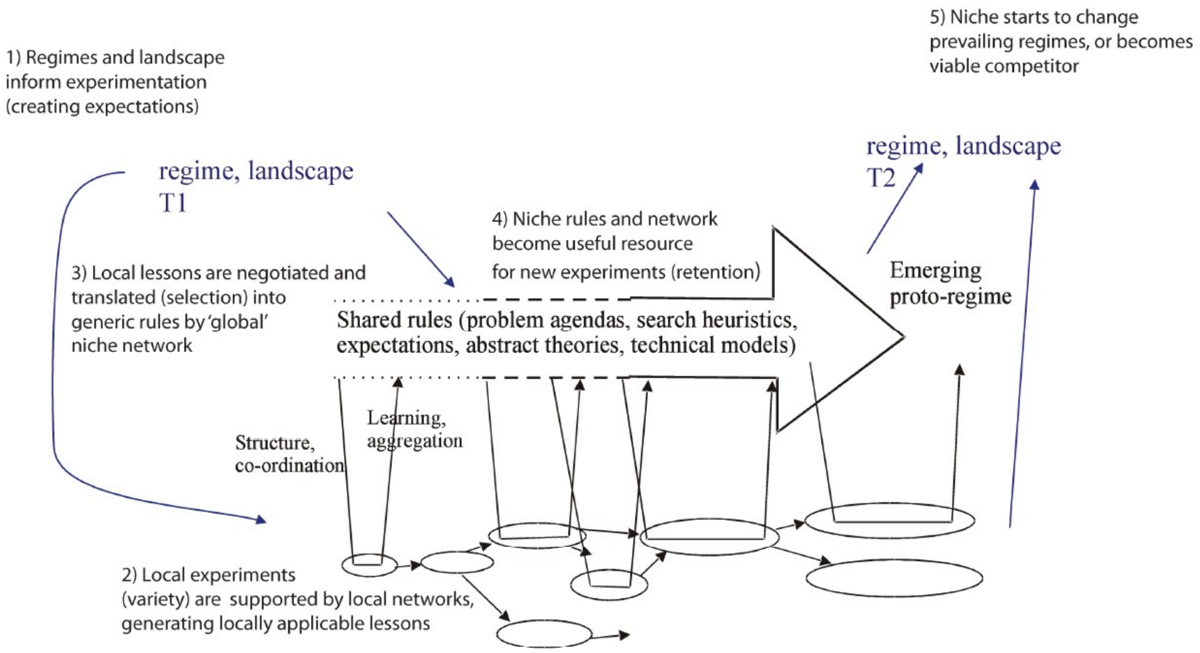
2.4.2.2. Networking activities

In the early stage of development, experimentations will bring about interactions among several actors sharing the same expectations ensuing the building of new social networks with new interdependencies. For the success of this process, these new social networks must include actors from different workgroups and be facilitated from within the network and between the actors. These activities are essential for creating a robust supply chain for necessary resources within the niche network (Hoogma; Kemp, et al., 2002).

2.4.2.3. Learning process

Hoogma et al. (2002) proposed two measures that indicate a successful niche development; quality of learning, and institutional embedding. This stress on the learning process as vital to the development of new technologies shows not only learning enables technology tuning to societal and user needs but also it is crucial to the process of regime shifts (van der Laak; Raven, et al., 2007, Schot and Geels, 2008). This confirms the importance of understanding the synergies between learning processes and regime shifts. While the outcomes of this process are unknown during the initial stage of development it revolves around; technical requirements, user profiling, socio-ecological impact, production and supply chain, and policies and regulatory framework (Hoogma; Kemp, et al., 2002). To improve learning, empirical studies showed that it must involve second-order learning including questioning the rules, norms, and the underlying assumptions (Schot and Geels, 2008).

Figure 3: SNM nurturing mechanisms



Importance of learning mechanisms, expectation and goals tuning, and experimentations (projects) in the development of radical innovation towards system changes. Source: (Smith and Raven, 2012).

2.4.2.4. Multilayer-Perspective Factors (MLP)

Hoogma et al. (2002) have determined other factors for niche innovation based on their originating source (i.e. market selection, regime pressure, internal characteristics, or landscape pressure) and they were identified through previous empirical researches, site visits, and literature research making them another fit reason for the case study. In their taxonomy, they broadly divided the categories into seven; Technological factors; Government policy and Regulations; Cultural and Physiological Factors; Demand Factors; Production Factors; Infrastructure and Maintenance; Undesirable Societal and Environmental Effects of the New Technology. However, due to the limited timeframe and scope of this research, only four factors are examined based on their relativity to the case study. The following (Table 1) shows these factors and their respective functions:

Table 1: Classification of factors affecting the development of biobased niche innovation.

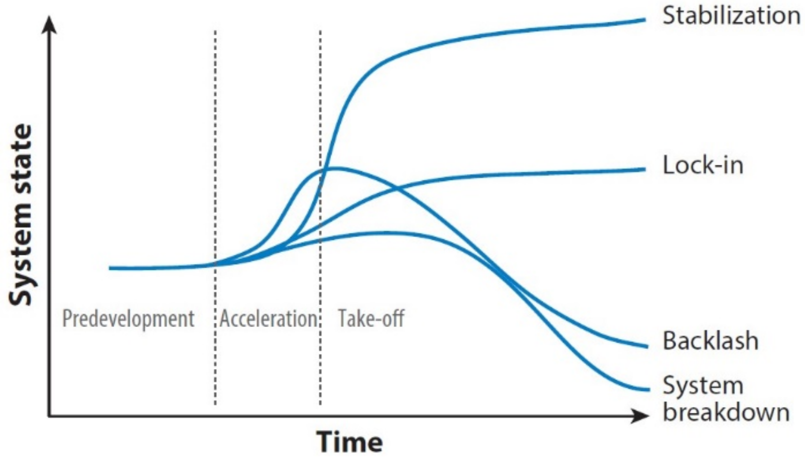
Factors	Function
Economic & Financial Factors	Economic landscape, and global economic crises, or major events. Banks are reluctant to invest in risky projects, government offering subsides for only R&D, and no funding mechanisms for marketing of the new technology except internal means.
Technical	Requirement of complementary technology for the innovation (supply shortage, expensive technology). Optimization of new technology for user needs because of being underdeveloped or expensive (low scale production). Consumers have not tested the technology in large scale.
Policies & Regulations	Absence of technology policy based on clear view of the future to guide the developers, planners, and investors towards sustainability. Regulatory framework may be a barrier for the development of new technology, and opposition from some actors against new regulations.
Infrastructure & Maintenance	Adaptation to infrastructure and new distribution system must be established. Labor requires training for the new technology. Infrastructure and maintenance investments are characterized by threshold value (must reach a certain number to render profit) regardless of the need for the infrastructure from new technology since early development. Lobby from current infrastructure groups against new technology infrastructure. Sunk investments.

Classification of MLP factors affecting the development of biobased niche innovation based on (Painuly, 2001, Kemp; Schot, et al., 1998).

2.5. Regime Shifts

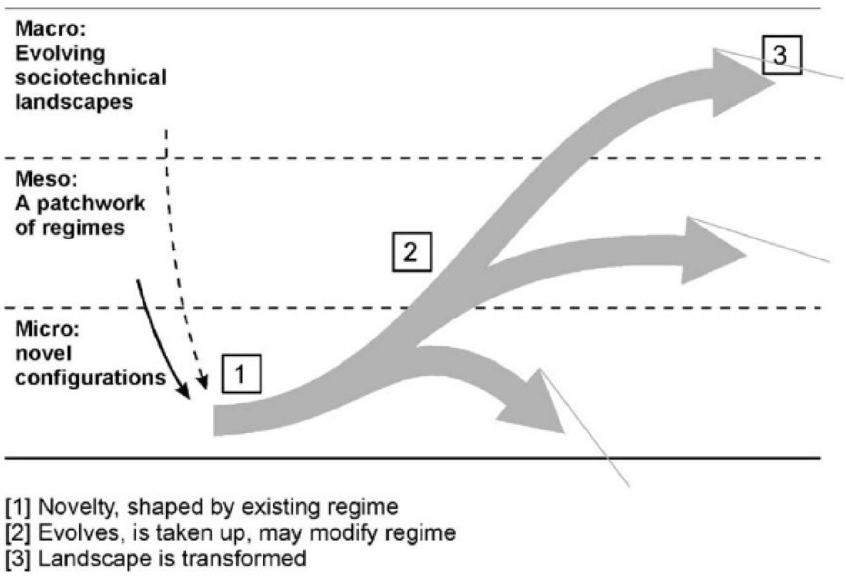
One of the assumptions in SNM and the MLP is that an empowered niche will create regime changes leading to niche becoming the mainstream and eventually transform into a regime. This process is incremental and implies combinations and sequences of mechanisms; denoting path-breaking patterns ensuing a trajectory towards its respective outcomes. Grin et al. (2010) suggest five trajectories that follow the interaction between the sociotechnical system components; Transformation; De-alignment and Realignment; Technological Substitution; Reconfiguration; and Mixing Pathway. Regardless of which trajectory, they are unpredictable rather projected (Figure 4, Figure 5). For this research, the focus is on the 'signs' of these changes that appear on the regime level of the sociotechnical system, in other words Regime Shifts. These shifts may lead to projecting one of the above trajectories nevertheless; projecting the system trajectory lies out of the scope of this research.

Figure 4: Transition pathways



Emerging niche and pressure from landscape resulting in coevolution of the sociotechnical regime changes. Source: (Loorbach; Frantzeskaki, et al., 2017).

Figure 5: Dynamics of sociotechnical system changes

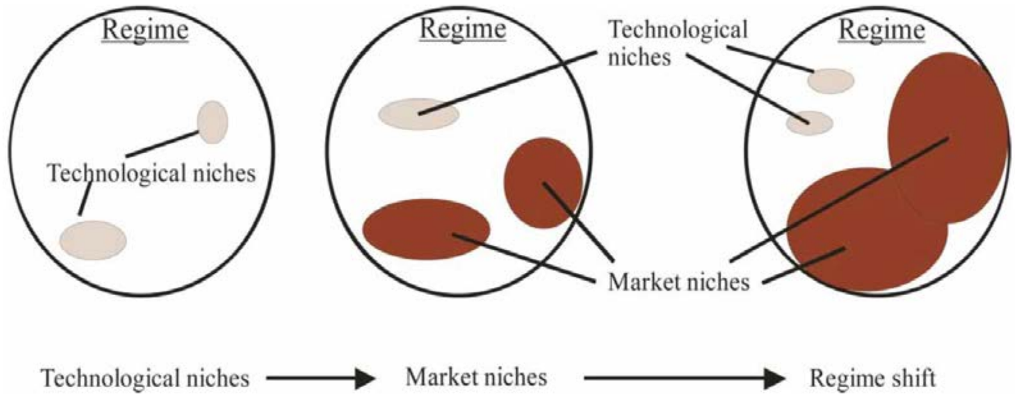


Dynamics of sociotechnical system changes leading to different pathways. Source: (Geels, 2002).

Schot and Geels (2008) suggest that the shift from a technology to another is an arduous process that depends mainly on the experimentation and learning processes of the niche, and further adjustments and reconfigurations of both niche and regime. On the hand, Hoogma et al. (2002) refer to coevolution which requires; several adaptations by the regime; selection through path-dependence of niche within the regime; and external events or opportunities from the landscape level. They also confirm the vital role that the niche internal nurturing processes from SNM play in bringing outsiders to the network who are willing to be involved and accept the new rules of the new technology in the regime shifts (Figure 6).

These regime shifts, are sometimes labelled regime disturbance or disruption in the system and it is safe to claim that they are hard to determine, but the following elements are some of the characteristics of these regime shifts (Grin; Rotmans, et al., 2010, Hoogma; Kemp, et al., 2002).

Figure 6: Niche Dynamics



Niche dynamics leading to regime shifts. Source: (Schot and Geels, 2008).

2.5.a. Interrelations between technological progress and the social and managerial environment

Radical innovation creates disruptions in the regime supply chain, user profiling, and management structures and relationships. Such disruption is met with resistance from industries and actors of the regime through vested-interests and selection pressure, entailing debates around the performance and impact of the new rising technology.

2.5.b. Specialized applications in the early stage of development

Existing regime technology tends to go through significant developments in response to the new radical technologies. At the same time, the latter poses little economic benefits in the landscape of the sociotechnical system. Existing technologies will then breakdown and favor specialized applications over protecting their viability (Grin; Rotmans, et al., 2010).

2.5.c. Involvement of related techniques

The technicality of new services provided by the regime technologies will include complementary technologies and entail changes to pricing in supply chains.

2.5.d. Social views on the new technology

Changes of perceptions among engineers, managers, and users on the viability of new technologies, which dramatically affect their market potentials. The further development of new technologies is subject to these perceptions, which fluctuate among different workgroups.

2.6. Technological Innovation Systems

One of the major shortcomings of TM and SNM is the lack of mechanisms to embed the actions made by the actors, institutions, and their strategies to reach their goals. This is probably due to the lack of extensive empirical evidences, which is addressed in chapter one of this research. It is safe to draw on the fact that most of the literature using TM and SNM have applied this framework on specific sectors mainly mobility and energy confirming Markard and Truffer's (2008) analysis of TM as an abstract framework that relied on institutionalization and structuration yet neglecting the governance and networking strategies within the socio-technical system (Fuenfschilling and Truffer, 2014).

A complementary but sometimes rival framework to TM is the Technological Innovation Systems (TIS), which gained substantial attention in literature based on its familiarity with the empirical situation for being more concerned with the meso and micro levels. The technological innovation system is defined by Bergek et al. (2008) as a "*… set of elements, including technologies, actors, networks, and institutions, which actively contribute to the development of a particular technology field*." This conceptualization of the TIS framework focuses on the functionality of the socio-technical components, their interdependence, and the synergies created out of these interactions within each of the system elements stressing on the notion of the *whole is greater than the sum of its parts*. Such components are manifested in the resourcing mechanisms, and the strategies used by institutions and actors through working collectively to develop, diffuse, and use the new innovative products or services (Bergek; Hekkert, et al., 2015).

The major difference between TIS and TM in their focus on innovation is that the former does not differentiate between radical and incremental innovation. Whereas the latter put more emphasis on empowering radical innovation to push for system changes (Markard; Raven, et al., 2012). With regard to sustainability goals and the Dutch context, the urgency of the transition goals requires not only incremental innovation but also radical that is able to change and redirect the regime trajectory to break the path-dependency. For that reason, this research focuses on enriching the TM-SNM framework through the empirical study of the radical innovation of lignin-based asphalt in the CBBD region. Furthermore, when comparing the TM framework with the TIS, the former ignores the dynamics between the individual actors in the sociotechnical system hence confirming the lack of the necessary empirical evidences required for a nuanced analysis (Markard and Truffer, 2008). Rauschmayer; Bauler, et al. (2015) address this gap in TM by adding the role of agency and the interactions between actors to introduce dynamics to the TM-SNM static framework. Fischer and Newig (2016) has then suggested the role of intermediaries to bridge the gap between institutions (static) and actors' actions (dynamic).

2.7. Conceptual framework

Conceptualizing transition management is not an easy task, de Haan and Rotmans (2011) have rendered examples from different prominent authors to warn of oversimplifying and forcing a unified conceptualization of transition theories. It is important however to stress on the complexity and the novelty of the subject of study, and the fact that transition theories are continuously evolving and *in transition* as well. Therefore, through the above literature review, it is possible to extract a slice of these theories to build a conceptual framework for this research albeit misjudgment to the whole transition process. This framework may serve as a baseline or a point of departure that integrates empirical research with narratives to explain a modest view of bioeconomy transition in the Netherlands.

The main hypothesis is that by nurturing and protecting the niche innovation from the selection forces of the landscape and regime, it will be able to generate pressure on the regime to accelerate the transition to sustainability. Nevertheless, radical niche is not the only pressure that contributes to the enforcement of regime shifts, the tension between the Landscape and the regime may open a window in the regime that hypothetically assist radical innovations (empowered by the niche) to influence regime shifts into a new state of equilibrium (bioeconomy).

The factors affecting the development of innovation in this research exist on all system levels including the internal nurturing processes in the protected space of niche. These factors may push for or prevent new experiments in innovative technologies that in a later stage, will be able to compete with the regime. These dynamics create stress inside the regime (along with its existing internal stress) and a state of urgency for adaptation, which if not timely met, may catalyze the process of reformation, causing system disruptions and further regime shifts.

The following diagram (Figure 7) illustrates the relationships and dynamics between different sociotechnical system components using the Transition Management, and Strategic Niche Management Theories. It shows the relationship between the independent variables including the factors, and their impact on the regime shift, which is dependent on these factors.

Figure 7: Conceptual framework

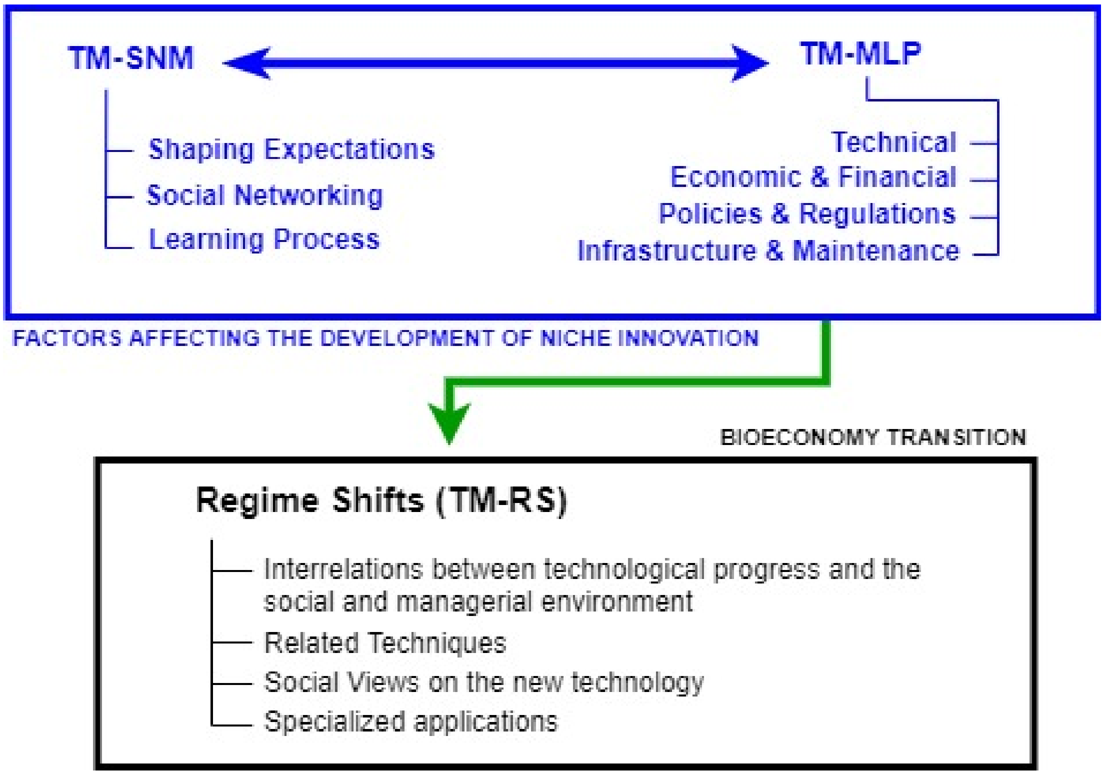


Diagram shows the factors existent in the three levels of the TM-MLP and the nurturing mechanisms of TM-SNM which affect the signs of regime shifts. The blue arrow refers to the interactions between both TM-MLP and TM-SNM, while the green arrow refers to the impact from the factors on the regime shifts and the bioeconomy transition respectively.

Chapter 3: Research design, methods, and limitations

3.1. Research Design

This research investigates which sociotechnical system factors explain the development of biobased niche innovation in the asphalt industry and how do these factors affect the regime shifts in the Dutch bioeconomy transition. To answer this type of question, a case study is chosen from the innovations developed inside the CBBD based on its radical characteristics and relevancy to the subject. Lignin-based asphalt or Bioasphalt is a new innovative technology aiming to displace the fossil-based binders in asphalt with lignin as a bio-binder. While transitions are processes characterized by nonlinearity, dynamic interdependencies, and entail structural changes, the data required here include but not limited to perceptions, motivations, patterns, interactions, interdependencies, policies, funding schemes, strategies, and plans related to the case study.

Accordingly, the strategy followed in this research is a deductive case study to fit the unit of analysis because, through its design, we will be able to trace the development processes, examine its patterns, and test the applicability of the theoretical framework. Through this research, an examination of the factors affecting the development of biobased niche innovation mentioned in the previous chapter will be compared with the case study of Bioasphalt to determine their empirical impact on the bioeconomy transition.

An exploration of a qualitative mix of subjective and objective indicators built from empirical situations, perceptions, motivations, is then converted into a synthetic analysis of a single case to deliver a comprehensive account of factors and events. To achieve this, Grin et al. (2010) have used the following methodology in their analysis of several case studies concerning SNM and TM. In their case studies, they emphasized on identifying patterns and mechanisms while following a careful process of converting the empirical experience into theoretical explanation through these following steps; detailed narrative explaining the history of the case without theories interference; explanation of the events through theories and hypothesis; conversion of the empirical events and findings into theory; and general explanation of the phenomena studied to generalize the case. Thus, by standardizing the above process, it will be possible to understand the interactions between the factors affecting Bioasphalt, in order to form reliable methodology for empirically testing the applicability of the MLP-SNM framework. To illustrate further, the research is formed into three phases:

First, an identification of the factors through TM-MLP, and TM-SNM framework to serve as a theoretical framework for mapping the factors (shown in chapter two).

Second, a careful examination of the historical background behind the development of Bioasphalt and the current state of the CBBD along with the changes of structure, norms, and culture that led to these developments. Such investigation implies the identification of the actors related to this new technology and their interdependencies along with the relationships they have established and resources collected. This is done through interviews with key actors in the case study (Bioasphalt) network, and secondary data collection of the related policies, funding schemes, and grey literature.

Third, comparing the empirical findings from the second phase with the theoretical framework, and generally explaining these findings through the scope of the MLP, SNM theories to reveal the applicability of the framework.

3.2. Data Collection

The mixed methodology between subjective and objective quantitative indicators is the most suitable to trace the process of Bioasphalt development. Knowing the potentials of Bioasphalt for example, will allow for the identification of changes in the material flows and supply chain of the incumbent industry.

3.2.a. Collection Methods

- Semi-structured interviews to generate data for the subjective and objective indicators and general information on the case study;
- Some questions were repeated to different sources to ensure for triangulating the results, and were shared with three academic transition management experts to confirm the validity of the analysis further;
- Secondary data was used to triangulate the collected data throughout the research phases as in CBBD publications, policy documents and, national and local government strategies;
- It is worth mentioning that data collection has reached saturation after the seventh interview, probably due to the small number of actors in the network.

3.2.b. Data collection limitation

The data collection phase in this research took place during the months of July and beginning of August 2020 during the pandemic of COVID-19. Therefore, five factors have affected the quantity and quality of data collected:

a. Summer vacation; during July, many employees are on long summer vacation and are not reachable during most of this period, which limited the number of interviews with potential respondents;
b. COVID-19; during the pandemic, all businesses and organizations followed the Dutch government obligations of social distancing. Therefore, offices were closed and employees worked from their homes starting March 2020 until the writing of this research. This meant that respondents relied on their emails for communication and some of them expressed their struggle to keep up with the emails and phone calls. For example, it took a potential respondent from the knowledge sector two months to respond to a request for an interview (May-July). Two other respondents have reacted after three emails claiming that they received an enormous amount of emails and they did not notice the first two interview requests. At the same time, their access to data in their offices were sometimes limited, which reflected on this research by lack of secondary data validation. To partially mitigate this issue, the design of the interview questions were revised during data collection phase to shorten the interview duration and appeal for interviewees;
c. Data sensitivity; some actors who work directly in the innovation of Bioasphalt and the CBBD expressed reluctance to share more details about future plans of development, strategies, or the roadmap of programs to protect their competitive advantages;
d. Secondary data limitation; no reliable data were found regarding bitumen imports or production levels in recent years due to the protection of market stability from the Dutch government, which implies an unstable supply of the material;
e. Demarcating the research topic; for the limitation of data collection time (one month) and analysis timeframe (one month) under the above COVID-19 measures, the initial

identification of eight TM-MLP factors affecting niche innovation is curtailed to four. This is to allow for more in-depth analysis rather than the breadth of the study albeit the effect on the reliability of the methodology.

3.3. Data Analysis

Interviews were recorded, transcribed and coded using Atlas.ti. These codes were grouped, categorized, and analyzed further to understand the relationships and identify interactions of the mechanisms and patterns of influence in the transition shift. The quotations were by the indicators and their respective variables and concepts, to allow for a nuanced analysis. During the coding, new indicators emerged, which were grouped under the relevant variable. Other emerged codes were given a related variable or category.

After coding, a co-occurrences table was created from the software, which shows the number of intersecting quotes between the indicators and variables. This is a helpful thought-provoking feature to show the interactions between the variables, although the numbers shown in the table do not necessarily include all the intersections, for that reason, an additional logical analysis of quotes is used.

Another feature used to analyze the interaction between the variables is the 'And' query. This feature shows commonality between the variables, which helps in understanding how the variables affect each other, being it negatively or positively.

3.4. Sampling Framework

Nonprobability and purposive sampling are central to this research, this is particularly important in the choice of the key innovative technology. For the limitation of the research time, only one technology is selected; Bioasphalt from the innovators' category in the CBBD. The technology selection is based on its fully developed state for demonstrations in order to determine the existence of majority of the factors.

In data collection, reliance on elite sampling to interview key positions for data collection was a compelling solution in this case, to reach for the influential actors and to mitigate the limitation mentioned at the end of this chapter. From those influential actors, I have used the snowball technique to reach for the rest of actors. In total, eleven interviews were conducted with actors in the Bioasphalt network and other related experts.

3.4.1. The Multi-Actors/Multi-layer Perspective

In transition management, analyzing the interdependencies and relationships between the actors requires the identification of key actors in relation to Bioasphalt inside and outside the CBBD. This is an absolute requirement for the reliability and validity of the research along with the triangulation of data. For the sensitivity of the information and the protection of the competitive advantages of the actors, quotes and references to the interviewees are completely anonymized. Below is a taxonomy of the eleven interviewees based on their role and the type of collected information from them:

3.4.1.a. Entrepreneurs/construction companies/contractors (C1): One contractor was interviewed twice in this category. Information obtained in this interview was related to the factors affecting their product, Bioasphalt, as well as their knowledge sharing mechanisms.

3.4.1.b. CBBD Management (C2): One member of the management team was interviewed twice to collect data regarding the history of the CBBD, its vision, goals, and actors along with information related to Bioasphalt and the CHAPLIN program. Secondary data from the internet archive's *wayback machine* were used to triangulate and complete the missing information.

3.4.1.c. Road Owners (C3): Identified as municipalities, provinces or the Rijkswaterstaat. One interview was conducted with an official from the Noord Holland Province, which is not part of or cooperating with the CBBD; however, they have plans for replacing the bitumen in their roads with lignin, and conducted several tests for these plans. A second interview was conducted with an official from the Rijkswaterstaat who recently started cooperating with the CBBD on demonstrations for the Bioasphalt.

3.4.1.d. Incumbent Industry (C4): Only one large bitumen producing company exists in the Bioasphalt network. One interview was conducted with a scientist working in their research department in the Netherlands to obtain data on their opinion about Bioasphalt, and the reasons behind their contribution to the network as well as general information on the bitumen industry. For the limitation of the research time, only direct influence is measured without considering the whole supply chain of asphalt or other related actors are taken into account as they are indirectly affected by the new technology although they are part of the regime.

3.4.1.e. Knowledge Institutions (C5): Six interviews were conducted with different experts of different backgrounds from WUR, UU, TNO, and AKC. The information provided assisted in understanding the flow of knowledge among different institutions inside the network and how new technologies can benefit from them to allow for second-order learning and upscaling their demonstrations.

3.5. Operationalization

The scope of this research stems from the importance of protection space stated in the SNM definition mentioned in the previous chapter as well as the MLP structure of sociotechnical systems. Although regime shifts may be ambiguous, but they are manifested in the process of coevolution and mutual adaption (Hoogma; Kemp, et al., 2002).

The case study shows relationships between the factors leading to radical innovation and the bioeconomy transition therefore, the identification of units of analysis is essential to form specific questions that can reveal mechanisms of interaction. An example would be to understand the impact of social networking among niche innovators on raw materials availability for the demonstration projects.

3.5.1. Operationalization Table

Table 2: Operationalization table

Theory	Variable	Sub-Variable	Type of Data	Indicator	Values
Independent Variable (Factors Affecting Development of Biobased Niche Innovation)					
Transition Management Multilevel Framework TM-MLP	Economic and Financial Factors	-Competition for resources	Objective	Availability of raw materials	-Available -Limited availability -Unavailable
			Subjective	Percentage of renewable materials in the LCA	-High -Fair -Low
		-High tax on profit	Objective	Taxation on profit compared to conventional technologies	-Higher than conventional tech tax -Same as conventional tech tax -Lower than conventional tech tax
		-Access to international markets	Objective	Ability to access international market	-Able, worldwide -Able, Europe -Unable
		-Credit worthiness	Subjective	Ability to access capital/loans/bonds	-Able, fully -Able, with limitations -Unable
		-Lack of financial instruments and subsidies -Lack of knowledge about financial means	Subjective	Perception of financial instruments and subsidies availability	-Available -Limited availability -Unavailable
		-Access to capital	Objective	Ability to access capital at the formation phase	-Able, fully -Able, with limitations -Unable
	Technical Factors	-Lack of fundamental and applied knowledge within niche to develop new technology	Objective	Access to knowledge	-Able, fully -Able, with limitations -Unable
		-Lack of knowledge of the potentials of the new tech by innovators	Subjective	Knowledge of technology potentials	-Fully aware -Moderately aware -Not aware
		-Limited experiments and testing	Subjective	Technology testing	-Yes -Yes, with

Theory	Variable	Sub-Variable	Type of Data	Indicator	Values
					limitations -No
		-Requirement of complementary technology that is unavailable or expensive	Subjective	Availability of complementary technology	-Available -Limited availability -Unavailable
		-Lack of experts involved in the product network	Subjective	Involvement of knowledge institutions in technology formation	-Fully involved -Limited engagement -Uninvolved
	Policies & Regulations	-Unfavourable regulations/policies or restrictive regulations	Objective	Regulatory restrictions	-Restrictive -Normal (Operating within the conventional tech regulations) -Supportive
		-Lobbying from bigger actors against new tech	Subjective	Lobbying from incumbent industry players on regulations	-Severe -Mild -None
		-Complicated documentation or procedures.	Subjective	Bureaucracy	-Complicated -Normal (as conventional tech) -Facilitated
	Infrastructure & Maintenance	-Installation of new infrastructure for new technology -Mismatch between tech and current infrastructure	Objective	Requirement for new infrastructure	-Requires new infrastructure -Requires infrastructure upgrades -Operating using the existing infrastructure
		-Low return of investment in new infrastructure - Relatively low profitability	Subjective	Willingness to invest in infrastructure of new technology	-Strong willingness -Moderate willingness -No willingness
		-Expensive spare parts	Subjective	Availability of spare parts	-Expensive compared to conventional technology -Same as conventional technology -Cheaper than conventional technology

Theory		Variable	Sub-Variable	Type of Data	Indicator	Values
			-Lack of experts to train, lack of training facilities	Subjective	Access to training mechanisms	-Available -Limited availability -Unavailable
			-Lack of skilled personnel, lack of capacity	Subjective	Access to skilled labor	-Available -Limited availability -Unavailable
			-Lack of institution/initiative to fix standards, lack of capacity, and lack of facilities for testing /certification	Objective	Compliance with certification	-Major changes in certification rubrics -Moderate reviews of rubrics -No change in compliance rubrics
			-Resistance from current regime actors to new technology	Subjective	Intensity of lobbying from incumbent industry against innovation	-Severe -Mild -None
Strategic Niche Management (SNM) Niche Internal Nurturing Processes	Shaping Expectations	Robust	-Willingness of actors to support and invest in new innovations -Actors vision is aligned and shared between many actors	Subjective	Expectation of innovation and willingness to support it	-Strong willingness -Moderate willingness -No willingness
		Specific	-Regulations and policies to support ongoing new technology experiments	Subjective	Effectiveness of niche space strategies to nurture innovation	-Highly effective -Neutral -Ineffective
		Aligned	-Projects or experiments aligned with expectations	Subjective	Alignment between experiments and expectations	-Complete matching -Somewhat matching -Mismatching
			-Involvement of public authorities in developing the vision	Objective	Involvement of public sector in vision formation	-Fully involved -Limited engagement -Uninvolved
	Social Networking	Broad	-Existence of: Supply chains, Users-producer relationships	Objective	Existence of supply chain user-producer in niche space	-Supply chain exists inside CBBD -Supply chain exists inside and outside CBBD -Supply chain exists outside CBBD
			-Sufficient user involvement in experiments	Subjective	Involvement of road owners during experimentation phase	-Fully involved -Limited engagement -Uninvolved

Theory		Variable	Sub-Variable	Type of Data	Indicator	Values
		Deep	-Highly skilled actors/labor -Organizational beliefs and sense of belonging -Available means of networking, and resourcing	Subjective	Experience of staff in management and organization, PR, and bio processes	-Highly experienced staff -Moderate experience staff -Novice staff
		Deep	-Organized coordination among actors	Subjective	Extent to which organization and coordination between actors in CBBD is developed	-Highly organized and coordinated -Moderate organization and coordination -No organization and coordination
		Expanding	-Involvement of vested-interests actors in the development stage of new tech (but without controlling)	Subjective	Involvement of conventional industry during the formation of innovation	-Fully involved -Limited engagement -Uninvolved
	Learning Process	First order learning	-Knowledge on market needs -Knowledge on opportunities for user behavior	Subjective	Awareness of market needs	-Highly knowledgeable -Moderate knowledge -Insignificant knowledge
	Learning Process	Second order learning	-Knowledge on which parts of new tech need development	Subjective	Future plans for development	-Exist and clear -Exist but not clear -Do not exist
	Learning Process	Second order learning	-Use of targeted marketing and tailored needs	Subjective	Marketing mechanisms	-Exist and clear -Exist but not clear -Do not exist
	Learning Process	Second order learning	-Knowledge of resources and actors of the supply chain	Subjective	Awareness of diverse resources and actors of the supply chain	-Fully aware -Moderately aware -Not aware
	Learning Process	Second order learning	-Learning by doing, and learning by using	Subjective	Existence of learning by doing, and learning by using mechanisms	-Exist and clear -Exist but not clear -Do not exist
	Learning Process	Second order learning	-Changes of values, norms, goals, and interests	Subjective	Changes of values, norms, goals, and interests	-Complete changes -Moderate changes -No changes

Theory	Concept	Variable	Sub-Variable	Type of Data	Indicator	Values
Dependent Variable (Bioeconomy Transition)						
Sociotechnical System Transition						
Transition Management Sociotechnical System Transition	Regime Shifts	Interrelations between technological progress and the social and managerial environment	-Vested interests in the niche	Subjective	Existence of large companies in niche	-High percentage -Moderate -Low
			-Innovation incubation under big actors.	Subjective	Incubation of innovation by incumbent regime large companies	-High -Moderate -Low
			-Public demand and awareness of new tech	Subjective	Perception of increasing demand for new technology	-High -Moderate -Low
			-Changes in regulations and policies in favor of new technologies	Subjective	Perception of the agreement on efficiency of conventional technologies	-Majority agreement -Some agreement -No consensus
				Objective	Formation of new regulations and policies regarding innovation	-Major new abiding regulations in favor of new technology in the last 10 years -Changes of policies in favor of new technology in the last 10 years -No changes
		Specialized applications	-Improved performance of current technologies	Subjective	Appearance of new specialized applications within the incumbent industry	-Many specialized applications -Some applications -No applications
		Related Techniques	-Incorporating new tech in parts of the regime -Changes in supply chain	Subjective	Disruption in the incumbent technology's supply chain	-Major disruption in supply chain -Some changes -No changes
		Social Views on the new technology	-Change of perception about new tech among different actors	Subjective	Change of perception of innovation among different actors in the last ten years	-Major changes in perception -Some changes -No changes
			-Changes of expectations and vision on market, user behavior, new technology	Objective	Changes of vision and structure in incumbent regime	-Major changes -Some changes -No changes

Operationalization of the four independent and dependent variables. Source: The author.

3.6. Validity and Reliability

To address the validity and reliability of the research, the strategy adapted from (Grin; Rotmans, et al., 2010) supports the internal validity of this research as this methodology has been already proved its validity in previous case studies. Meanwhile, triangulation of data is central to the collection process, by collecting data from different resources and validating them with multiple other sources through the interview questions, and comparison with literature. At the end of the research, the results were shared with key academic experts in the biobased economy in the Netherlands, which added an extra layer of validation before publishing the conclusion.

To ensure external validity, the research is designed to stem hypothesis from existing theories (SNM, and TM) and test them on the empirical situation, to compare both theoretical and empirical situations in order to test the applicability of the framework. While for reliability, a case protocol and database of the case study are provided in the annex.

Innovation is a case-sensitive study; therefore, generalization of the findings may render the analysis invalid. In addition, most of the indicators are perceptions (which are sometimes biased) and interactions between actors are mostly not subject to triangulation with secondary data, which also affects the validity, and reliability of the results.

Chapter 4: Presentation of data and analysis

In this chapter, the data analysis follows with a thorough explanation from the variables level down to the level of indicators to structure a comprehensive analysis of the findings. The history and the governance of the case study is presented at the beginning followed by a descriptive analysis of the data collected in order to accurately answer the first research sub-question, which is static. For the second and the third sub-questions, an analysis of the interdependencies between the factors is rendered to present the dynamism of the interactions.

4.1. The Circular Biobased Delta

The Biobased Delta was formed in 2012 after the first Biobased Congress on October same year, which took place in Goes, Zuid-Beveland with the aim to support an economy revolving around the use of biomass instead of fossil fuel using partial funds from Southwest Netherlands Chamber of Commerce, the Province of North Brabant and the Province of Zeeland. This triple-helix cooperation combined several actors from the government, industries, companies, chamber of commerce, and knowledge institutions working in the region to connect agro-business with the chemical industry under the motto of "*Agro meets chemistry*" in order to promote the development of green products in the Southwest of the Netherlands and the Flanders. Two years later, this public-private partnership, Biobased Delta has matured into a registered foundation at the chamber of commerce, and set specific vision and goals under the management of its new director who was also the general manager of a large multinational chemicals company that has several offices globally.

Based on the depleting fossil fuel and the increasing tax on CO_2 emissions, these goals aimed at; increasing the investments in biobased innovations up to 600 million euros in 2020; creating thousands of jobs or attract companies and start-ups to the region; and intensifying the cooperation among partners located within the geographic area of the cooperation. Using their infrastructure and geographic location as the main competitive advantages, the emphasis on creating a regional biobased economy has taken a central place in the publications of the BBD. Therefore, the focus of this newly formed foundation was on three main points; Green raw materials; Green building blocks; and Making the industrial processes more sustainable. Meanwhile, the structure of the cooperation has changed and committees were discontinued and replaced by advisory councils (i.e. the Scientific Advisory Council, and SMEs Advisory Council). Biobased Delta has then redirected its attention towards public relations and communication to promote itself for the international players as an attractive location for investments in green products.

In their 2014 annual report (CBBD, 2014), the use of lignin was briefly mentioned as a potential bio-binder for the asphalt industry rather without concrete plans for developing such innovation in the updated business plan covering the years from 2014 until 2017. On the other hand, the focus of this plan was to attract more businesses in the region and create a strong bioeconomy through "*Smart Specialization*." This was evidently clear in the promotion of Biorizon; a multinational cooperation program between the Dutch TNO and Belgian VITO research institutions aiming to attract global leaders in bio production and processing to invest in the region and accelerate innovations in bio aromatics. In this program, the BBD has relied on its infrastructure, namely the Green Chemistry Campus (founded in 2013) located on the SABIC site in Bergen op Zoom (Zuid-Holland), which acts as an incubator where agro and chemistry businesses accelerate their biobased innovations.

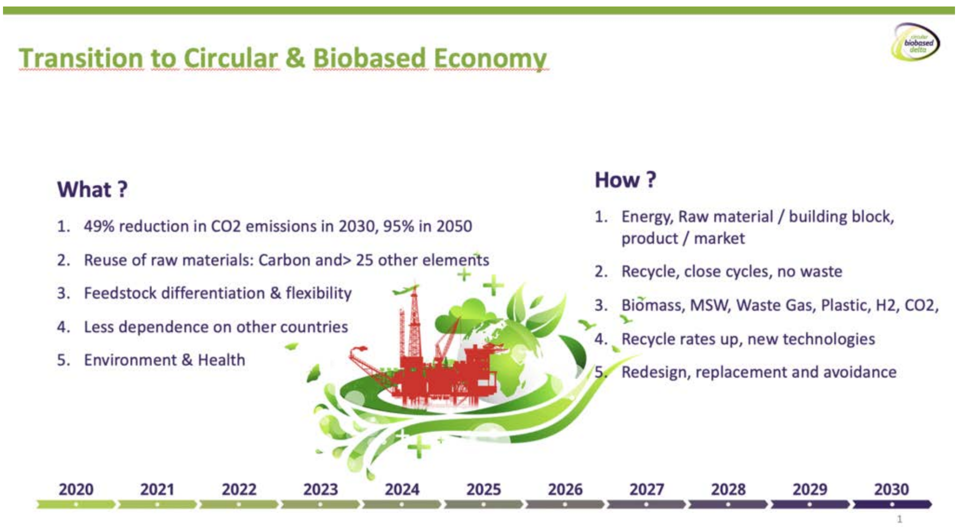
During those years, the BBD has offered its infrastructure through cooperation between its members, while a comprehensive database of funding resources was available on its website to attract SMEs and entrepreneurs to steer innovation in biobased production. The BBD has then celebrated the first test section of lignin-based asphalt, which took place in 2015 by naming their 2016 report after it and adding a picture of the director riding a motorbike on this road section to mark its opening and market the event from their side.

In the 2016-2018 multiyear plan (CBBD, 2017), the reconfiguration of networking and governance mechanisms of the BBD Foundation has taken central attention. The organization structure and board members changed twice, and goals were redefined to emphasize on "*The Next Economy*." The majority of the core team were officials from the involved municipalities while the board members were mainly from large companies involved in the regional network. The promotion of the geographic location and exceptional infrastructure in the agro-chemical industries were adorned with the introduction of another program: Redefinery; for the construction of a bio refinery that produces sugar and lignin to feed in the supply chain of the established chemicals industry. It aspired to convert sugars into chemical products and materials.

This reorganization has included a plan to align with the government policy for reaching 100% circularity by 2050 and paying more attention to the raw materials lifecycle. In the meantime, the interest in the use of lignin as a bio binder has gained larger momentum to the extent that in 2020, a new program designed to study the development of lignin use in asphalt was formed; the CHAPLIN program.

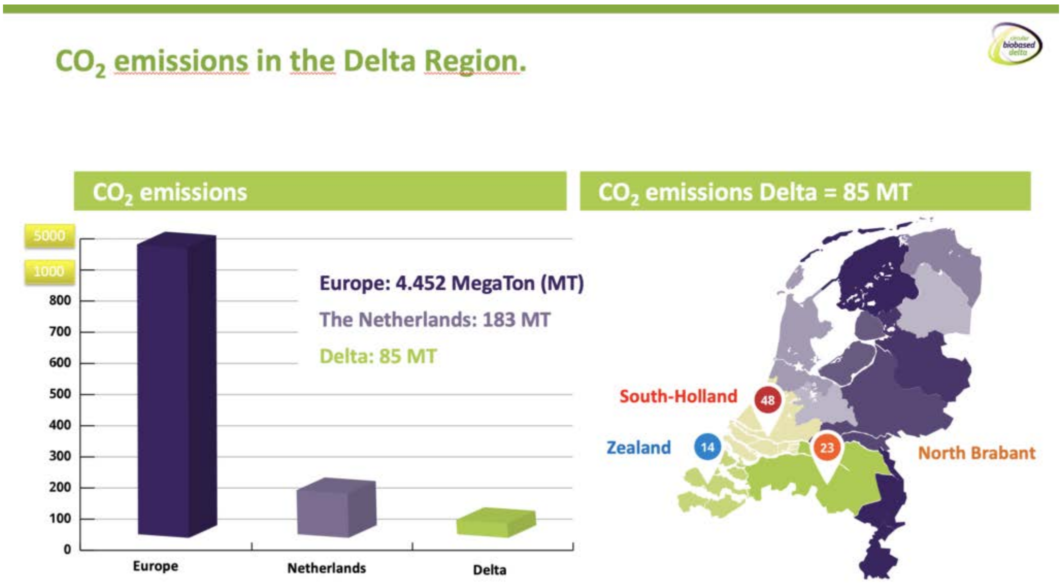
The BBD Foundation reaction to align with government policy has led to not only change its name to become the Circular Biobased Delta in the first quarter of 2020 but also downsize its board members to become only seven, and create an Acceleration Team to further steer innovation and cooperation in the region. In this latest version of the CBBD, the ultimate goal is to reduce 10 mt of CO_2 emissions in the region by 2030 to support the Dutch circular economy plan for the same decade (Figure 8, Figure 9).

Figure 8: CBBD transition goals.



The CBBD plan over the coming ten years period. Source: https://biobaseddelta.com/10-year-plan

Figure 9: CBBD CO_2 emission goals.



CO_2 emission levels in the provinces of Zuid Holland, Zeeland, and Noord Brabant compared to National and European levels. Source: https://biobaseddelta.com/10-year-plan

4.2. Bioasphalt

Bioasphalt, biobased asphalt, or lignin-based asphalt is a new product that started a decade ago in the labs of Wageningen University – Food and Biobased Research (WUR). According to WUR, lignin holds exceptional properties that rivals bitumen as a binder in the asphalt mix. Being a natural adhesive that gives plants its rigidity and strength, it can also give asphalt the same properties along with weatherproofing if it replaces bitumen. Not only had these properties motivated researches in bio-binders but also the abundance of lignin found in nature and the lower amount of bitumen available every year. Most of the lignin in the Dutch and international markets is a by-product of the pulp and paper industry, and comes in the form of powder unlike the liquid form of bitumen. So far, researchers have managed to replace only 50% of bitumen with lignin in the asphalt mix, and further plans exist to displace bitumen in the formula albeit the need for further road sections to test and develop the material.

Two main patents in lignin-based asphalt mixing techniques are currently available in the Netherlands; the first by WUR-AKC, which is more developed and tested on different road sections for over five years now. In this technique, the asphalt mill is fed manually with the lignin powder while insignificant adjustments in the mill operation are made. The second patent is by WUR-TNO in which the lignin is blended in an automated manner also with minor adjustments in the mill operation. This second mixing technique is still underdevelopment with no commercial use yet.

The estimated lifetime of the bitumen-based road is 10 to 15 years while the oldest lignin-based road section is just five years hence, road owners still consider it in an infancy stage and only time can prove its performance before large-scale deployment. Today, most contractors working with Bioasphalt are SMEs with minor exceptions.

On the other hand, the mainstreamed bitumen-based asphalt industry in the Netherlands is facing major disruptions in the supply of bitumen. The amount of bitumen produced is not enough for the roadworks required annually in the Netherlands and most of it is imported from other European countries according to experts interviewed and working in the field. Two main factors contribute to this; the depleting fossil fuel resources, and the enhanced technologies in crude oil refining. While the latter is supported by the oil industry to maximize their profit, the Dutch government has blessed this policy to foster its top sector; the chemicals industry. On the technical side, bitumen is the residue of crude oil after refining meaning that more refinement of crude oil results in less quality and quantity of bitumen produced.

4.3. The Bioasphalt Network

As a research institution, WUR has developed the technology in the early 2010s in the laboratories, and sought cooperation with the industry then teamed up with SMEs to take the innovation to the streets. In 2015, the first testing of lignin-based asphalt was in an industrial estate in Sluiskil, in the Kanaalzone between Terneuzen and Ghent. This testing section was commissioned by the Zeeland Seaports Company and in cooperation between WUR, H4A, AKC, with investments from the Province of Zeeland (IIZ, 2015). Since that date, an estimated number of fifteen test sections were executed in several provinces in the Netherlands. In 2019, the CBBD has approached several actors, among them WUR, AKC, UU, and other contractors, to form the CHAPLIN program in order to generate resources and scale up the innovation.

4.3.1. The CHAPLIN: Collaboration in aspHalt Applications with LIgniN

CHAPLIN is the latest program by the CBBD to stimulate the development of lignin use in asphalt in the Netherlands and other countries. This program adopted the triple helix methodology uniting 22 partners, and 11 test sections listed under this program although some of these sections are older than this program. This overarching program has two projects running on governmental subsidies; the CHAPLIN-TKI to look into the development of Bioasphalt technology; and CHAPLIN-XL, which has a larger subsidy to look into the LCA of Dutch lignin as the raw material for Bioasphalt.

Although none of the 22 partners of the CHAPLIN program is a member of the CBBD, the latter has since played the role of the intermediary between the innovation and the government to scale up the technology, and involve more actors in the network through social networking. The Rijkswaterstaat came across Bioasphalt through the CBBD by chance in a meeting related to other business. In March 2020, both met again to discuss possible cooperation to allow for a demonstration section on the national roads. With no specific targets or a shared vision for the program or the cooperation with RWS, the expansion of this network is generally dependent mainly on word of mouth in official meetings and smaller networks established by the actors. Each of the CHAPLIN members have formed other networks away from the CBBD; Dura Veermeer has secured a cooperation with Noord Holland Province; TNO have talks with RWS regarding developing the technology; AKC has a network of SMEs and contractors in the asphalt industry; other contractors have established connections with municipalities to realize demonstrations on the roads.

As the government is the main, if not the only, customer for roads, being the regulator and the market, the government has the biggest role in driving this innovation however this is not the case in Bioasphalt as the technology has faced several barriers which are discussed in the next section. Two strategies were adapted by the CHAPLIN actors, the contractors and the

AKC are planning to market Bioasphalt to municipalities and gain a slice in municipal roads market then upscale to the national roads, which represent 85% of the Dutch roads network. On the other hand, the CBBD is focusing on the 15% represented by national roads through talks with the RWS to gain their support and conquer the more important market. Meanwhile, research institutions are working on developing the technical and environmental performance of the material.

4.4. Data analysis

In this section, answers to the research sub-questions are provided in line with the data collected from the interviews and the secondary resources. For each sub-question, an analysis of the set of related indicators and variables from the operationalization of the theoretical framework is provided. At the end of each section, the variables induced from the empirical situation are also categorized, presented, and discussed. Meanwhile, the interactions between the variables are presented within the description of the results under each variable.

4.4.1. Factors affecting the development of biobased niche innovation

The first sub-question in this research is to explain how the sociotechnical system influences the development of biobased niche innovation through the factors that allow or prevent Bioasphalt from developing and gaining shares in the asphalt market, which were mentioned in chapter two. According to the theoretical framework, the nurturing mechanisms established by the niche space are essential for the development of the innovative technologies. However, through the empirical findings in the case of Bioasphalt, these mechanisms are not exclusive to the CBBD but also all actors have used different support mechanisms to steer the development of the technology even before joining the CBBD. The main common drivers in this process were the shared motivation to push for green solutions and the transition to a sustainable product in time with, the reduction of bitumen in the market. On the other hand, the lack of a clear and shared vision, along with bold targets are derailing this development.

The focus of the data collection was on the seven factors; however, other factors have emerged through the interviews with the key actors in the Bioasphalt network.

4.4.1.a. Economic and Financial Factors

Indicators: *Availability of raw materials; Percentage of renewable materials in the LCA; Taxation on profit compared to conventional technologies; Ability to access international market; Ability to access capital/loans/bonds; Perception of financial instruments and subsidies availability; Ability to access capital at the formation phase.*

In order for the Netherlands to use Bioasphalt in all of its roads, an extensive exploitation of lignin must be made as the amount of lignin produced in the country is minimal and not up to the required quality for road constructions. Therefore, an enormous amount of bio refineries is required, which will complicate the MKI value of the material; hence, the investments needed in the production of lignin in the Netherlands will not render the anticipated environmental benefits of using it in asphalt. Therefore, in order to develop or scale up this technology, reliance on import is inevitable. Although this might create vulnerability for the Dutch economy in the future however, imports of materials seems to be the norm in the Netherlands. On the other hand, this low quality and quantity of the raw material in the Netherlands has in fact, pushed some actors to explore international markets however, the pandemic has negatively affected the international market this year. Several actors who agreed on the potentials of lignin and stated that the amount needed for even a 50% replacement of bitumen is not locally available also confirmed this.

The pulp and paper industry, which produces the majority of lignin in the Netherlands, is burning this byproduct in return of energy. This creates a new challenge for Bioasphalt in its supply chain; to find an alternative for the pulp industry that can cover the energy need from lignin for the pulp industry. It seems that the global availability and material properties have motivated the actors to be involved in the program while ignoring the Dutch lignin properties.

On the financial aspect, the Dutch government strategy made use of several financial instruments and incentives to stimulate innovation in the biobased economy like the *Innovatiekrediet*[1], or *Regeling Groenprojecten*[2], which are green loans. On the procurement side, the *Innovatiegericht Inkopen* suggests spending 2.5% of the procurement budgets on innovative solutions, and created a comprehensive guide for biobased procurement[3], loans, and grants for entrepreneurs. Actors have moved to build coalitions like both of CHAPLIN projects to receive funding from the RVO subsidies, which accelerated the demonstrations for Bioasphalt and avoid financial risks associated with loans. Interviewees who expressed the ability to access funds even in the early formation stage of the technology confirmed this. While road owners receive a modest tax reduction for making bio purchases, two interviewee from different categories claimed that such incentives are not enough while taxation on profit for Bioasphalt remained similar to bitumen-based asphalt companies.

According to Kwant; Hamer, et al. (2018), 1258 organizations were active in biobased economy in 2017, 80% of them are SMEs like most of the contractors working in Bioasphalt. Therefore, they are profit-making organizations that do not afford the financial risks associated with innovation and would preferably depend on grants for their growth. At the same time, the CBBD is not offering any financial support but relying on building alliances for the same cause. Meanwhile, the province of Noord Holland had a different instrument for financial support using the *Innovatiegericht Inkopen*. The above shows a lack of integrated financial schemes that encourage innovation; a revision to interest rates and taxation is required for sustainable financial models.

Nowadays, the culture of circular economy is gaining momentum, which is reflected in the consumer's evaluation of tenders especially in terms of LCA. Such move raises questions about the percentage of renewable resources used for the production of Bioasphalt, which remain unanswered in all interviews. A popular explanation to this is that Bioasphalt is in its early technical stage of development, and more research is required to determine its LCA and MKI.

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[1] Innovation credit; a total budget of 40 million euros in 2020 were made available by EZK for innovative projects supporting the sustainability of the Dutch economy. https://www.rvo.nl/subsidie-en-financieringswijzer/innovatiekrediet

[2] Green Projects Scheme; jointly offered by the Rijkswaterstaat and EZK, the loans with the low interest rates and green certificates are for innovations in the construction projects, environment technology, and circular economy. https://www.rvo.nl/subsidie-en-financieringswijzer/regeling-groenprojecten

[3] PIANOo, the Dutch Procurement Expertise Center has a dedicated section on their website for the tools, practices, and a practical guide to explain the benefits of biobased procurements and how to make use of it. https://www.pianoo.nl/nl/themas/innovatiegericht-inkopen

This empirically confirms Egenolf and Bringezu (2019) claim about the need for developing indicators for the bioeconomy and the required reevaluation of calculation methodologies of environmental indicators. For these reasons, the CBBD has created the CHAPLIN-XL program to investigate the LCA of lignin and improve it. At the same time, one actor has plans to enhance the LCA of Bioasphalt but preferred not to include it in this research for their competitive advantage, which is another sign for the division of views on the development of material inside the Bioasphalt network.

4.4.1.b. Technical Factors

Indicators: *Access to knowledge; Knowledge of technology potentials; Technology testing; Availability of complementary technology; Involvement of knowledge institutions in technology formation.*

With five knowledge institutions involved in the network (Table 3), access to knowledge is not an issue for the actors. This access to knowledge is one of the important factors for improving the technical performance of the material as well as expanding the network, since the outcomes of experiments is used to promote Bioasphalt for road owners. While competition exists between some actors, they expressed their willingness to support each other for the development of Bioasphalt, basing this support on quality assurance of Bioasphalt, which indirectly affects their own business through the level of trust in the product by road owners.

This same mutual agreement between actors applies to their knowledge of Bioasphalt potentials as all actors have a strong belief in the prospects of lignin to replace bitumen in asphalt albeit being an immature technology from the road owners' point of view. These potentials are what kept the actors motivated to seek test sections in order to move from the laboratory to practice. So far, fifteen demonstration roads were made in different places around the Netherlands with a maximum replacement of 50% of bitumen with lignin (CBBD, 2020). Although some of these demonstration roads existed before the formation of CHAPLIN, it is not clear how many locations were secured by the CBBD. Still several actors agreed on the CBBD prominent role in finding test sections and promoting the technology.

The complementary industry in this case study is the development of the lignin industry and related processes. It appears that the CBBD was motivated by the development of its bio-refinery to explore the use of lignin in other industries and create a value chain for the Bioasphalt with lignin. The challenge in this complementary industry is the quality and quantity of lignin as explained in the previous factors, which not only affects the quality of the Bioasphalt but also the deployment of the technology, as RWS has also expressed their concerns on the LCA of Bioasphalt based on the processing techniques of the lignin. On the other hand, one of the goals of the CHAPLIN-XL program is to improve the LCA of Bioasphalt through enhancing the processing techniques of the complementary industry; lignin.

> *"..the issue is the origin of the resource (lignin). What was the land use? Has pesticides been used for that? Has fertilizer been used for the biobased resource? What's the method of drying of lignin? I think that's the question; on the supply side of the resources." C3*

Table 3: Knowledge institutions in the Bioasphalt network

Actor	Role in Bioasphalt
WUR	Development of the technology and mixing.
UU	Development of LCA, regulations, and standards development.
Q8, AKC	Offering laboratories and knowledge on the bitumen in asphalt.
TNO	Testing of existing road sections.

Sectoral development by each knowledge institution involved. Source: The author.

4.4.1.c. Policies and Regulations Factors

Indicators: *Regulatory restrictions; Lobbying from incumbent industry players on regulations; Bureaucracy.*

Regulations and policies have posed major challenges to all actors due to the fact that the existing regulations on local, national, and supranational levels are based on the bitumen asphalt industry and require changes in the standards and norms. The European Standardization Committee would not standardize Bioasphalt at this stage unless it gains enough ground in the market-shares battle. This reactive policy is an obstacle to innovation as it leaves Bioasphalt exposed to pressure forces from the incumbent regime and create a death valley for innovations.

> "*One of the main issues we really need to solve with each other is the technical regulations and the trust in innovations. It's important to really look where the old current regulations come from, most of the times they are based on an idea from the history, and it's really hard to break those ideas down than to create new innovation. So the barriers for innovation are partly also in the current regulation." C3*

This variable has a strong relationship with the indicators used for environmental assessments like the MKI value or LCA, as well as the procurement policies by governmental bodies and certification for bio products in general. For example, one of the actors spent three years to certify their bio product, while several experts agreed on the injustice of the MKI value, and LCA on biobased products. Two interviewees have expressed their doubts in the certification agents due to vested interests from bitumen-related industries.

> *"I think but I can't prove it that the companies who give the certificates are also sometimes involved with products or projects of big bitumen asphalt companies. And I think they don't like this bio product. And they are continuously asking questions; Are you sure that it has good strength? Good lifetime? There are a lot of influences which I can't see and I'm 100% sure that they are there, but it's not concrete." C1*

Logically, the actor in the C1 category is the most motivated for changing the regime and developing their technology, but triangulating the above quote with an actor from the C3 category as well as other actors validates the above statement. The reality is that Bioasphalt is unable to test on the national roads mainly because of technical regulations that favor bitumen-based asphalt over biobased asphalt.

4.4.1.d. Infrastructure and Maintenance Factors

Indicators: *Requirement for new infrastructure; Willingness to invest in infrastructure for new technology; Availability of spare parts; Access to training mechanisms; Access to skilled labor;*

Compliance with certification; Intensity of lobbying from incumbent industry against innovation.

In both of the techniques developed by WUR-AKC, and WUR-TNO they considered minimal adjustments in the current asphalt mills when they designed this new technology. Accordingly, Bioasphalt is produced in the same bitumen-based asphalt plant, yet the challenge is how to mix the lignin, which comes in the form of powder, with the other ingredients in the mill. In both techniques, the changes in the asphalt mills seem to be affordable rather it is a question of workflow and efficiency. Therefore, the cost and availability of spare parts are the same as the bitumen industry, and these indicators are irrelevant to the case. This is a driver for contractors to step in this technology since they already have the infrastructure, and only modest investments are required. Although the alignment between both techniques can boost the development of Bioasphalt in general, the expectations about the technology is not shared among both, as they seemed only to share tasks assigned to them through the CHAPLIN program. This variation in vision may potentially affect the technical development and the commercialization of Bioasphalt in general.

The availability of training mechanisms, skilled staff, and professionals are also irrelevant in the Dutch context for this case due to the culture of knowledge-industrial cooperation in the Netherlands and the entrepreneurial spirit.

4.4.1.e. Shaping Expectations

Indicators: *Expectations of innovation and willingness to support it; Effectiveness of niche space strategies to nurture innovation; Alignment between experiments and expectations; Involvement of public sector in vision formation.*

Through the interviews with different actors in the CHAPLIN program and the CBBD, all actors revealed a strong willingness to support Bioasphalt in every possible way even if this support is for their competitors. In this technology, several networks were also created by actors to generate support and resources for their product based on a shared vision. However, this vision is exclusive to the sub-networks and not shared among the broader network of the technology as the large bitumen producers and asphalt contractors are still missing, while RWS being a vital road owner and regulator is not yet involved. For example, one interviewee's ultimate vision is to use 100% lignin-based asphalt in the near future, on the other hand another one expressed that this vision is not feasible in the coming decades, while a third one could not comment on this as they have no information about the performance of this product. These different expectations may affect the transition pathways in the future.

> *"Yeah, we don't have for this product a clear mission and vision, but it's just a pilot not an exercise as we didn't know if we were going to make it. We tried to make asphalt with something green, and we didn't know if it should succeed. Now after successful demonstrations, we try to refine it.." C1*

When triangulating the above data with experts in transition management in the Netherlands, they confirmed that this lack of shared vision and targets is negatively affecting the resourcing and networking expansion through less coordination between the actors.

Meanwhile, most of the demonstration projects for Bioasphalt were created for municipal roads in the southern parts of the kingdom with few exceptions on provincial roads in the

Province of Noord Holland, which has no relation to the CBBD. This shows the alignment of expectations from a market point of view but not a technical one.

4.4.1.f. Social Networking

Indicators: *Existence of supply chain user-producer in niche space; Involvement of road owners during experimentation phase; Experience of staff in management and organization, PR, and bio processes; Extent to which organization and coordination between actors in CBBD is developed; Involvement of conventional industry during the formation of innovation.*

It is worth mentioning that, RWS owns the national highways comprising 15% of the roads network in the Netherlands, while the municipalities, provinces, and private parties own the other 85% of the network. In the asphalt industry, the highways are an essential market where the business thrives. While the government regardless of its level is considered the only customer for Bioasphalt, and therefore their involvement in the experimentation is crucial to its success as they are the market and the legislative part of the sociotechnical system. Several municipalities and provinces expressed their preserved interest in the technology. In contrast, the involvement of the provincial government of Noord Holland for example, has created a change in the procurement policy of asphalt inside the province.

> *"There is a procedure, some monitoring plan for this, there is a document which describes what are necessary steps to get certification. The contractor is continually testing how the sections in the project holds and manage several points of testing and also the drawbacks while the province shares the costs of repaire. And then at a certain point I don't know exactly when but at a certain moment the project will prove itself to be reliable and useful to scale up."C3*

Regardless of their cooperation in the smaller networks, the Scandinavian lignin companies who are considered the largest producers are absent from the CHAPLIN network as the focus here is on the local producers only, albeit the quality and quantity produced by the Dutch companies. At the same time, large bitumen producers and bitumen-based asphalt companies are not involved in the Bioasphalt experimentations except for one company that has closed its refineries in the Netherlands and focused on bitumen research.

Although some actors have worked with lignin in asphalt for over ten years, all of them are still experimenting with its use in asphalt. The coordination between the actors fostered their learning processes, and generated resources like infrastructure and knowledge, which is reflected in their success to obtain grants from the government to further learn about and develop the technology.

4.4.1.g. Learning Processes

Indicators: *Awareness of market needs; Future plans for development; Marketing mechanisms; Awareness of diverse resources and actors of the supply chain; Existence of learning by doing, and learning by using mechanisms; Changes of values, norms, goals, and interests.*

The asphalt market is not diverse and some actors used their accumulated experience to establish market dominance (in Bioasphalt) and relied on this experience as a valuable source. They have also gained insights on the market needs from municipal to national levels showing first-order learning mechanisms. In such type of technology, the main learning methodology is Learning by Doing which is typical in the asphalt industry. Testing the technology on national roads is still missing and that is another reason for actors to seek RWS approval for demonstration to develop the Bioasphalt performance.

Furthermore, all respondents showed their awareness on the diverse resources and actors outside the CBBD, and have existing plans for the development of the technology. For example, RWS has expressed concerns with the LCA, whereas some actors who have not been in contact with RWS have plans for reducing the temperature of the asphalt and looking at the recyclability of the lignin-based solution to improve the LCA using renewable energy for the processing of lignin.

4.4.1.h. Other factors induced from the empirical findings

During the data collection phase, other factors that affect the development of biobased innovation were empirically found. By asking different categories of actors on these factors and their effect, they confirmed their influence on the development process of the Bioasphalt. Categorized according to the theoretical framework, these factors are presented in the following lines, including those not considered in the framework, but a general description of their category can be found in Annex 1: Case Study Protocol.

4.4.1.h.1. Economic and Financial Factors

Indicators*: Circular economy; COVID-19; Fragmentation of the Rijkswaterstaat; Recyclable asphalt technology; Reduced production of bitumen; Motivation of actors; and SMEs.*

In the Dutch context, the government plans to reach a 50% circular economy by 2030, and 100% by 2050 has pushed road owners (which are mainly governmental bodies) to favor the purchasing of bitumen-based asphalt over biobased asphalt to meet the government's ambitious plans for circularity on time. The same 2030-2050 plan provoked a sense of urgency to reduce CO_2 emissions, incorporate green solutions, and investigate the lifecycle of the products. As a matter of fact, bitumen asphalt is tried and tested by road owners, they do not have to speculate its performance, and it can be instantly implemented. Meanwhile, biobased asphalt requires time (10 years in the lifetime of roads) for testing and development to prove its high performance or at least acceptable performance standards compared to its bitumen-based counterpart. In the meantime, the reduced amount of bitumen was the principal factor that has pushed actors to be involved in this network.

Although this hype around CE created a partial blockage for bio procurements, it has also pushed the actors of this network to seek green alternatives to fossil fuel.

At the same time, the project-oriented mindset of the project managers working for road owners, who want to get their projects done without further risk-taking has also affected Biobased innovation negatively. This challenge is due to the procurement strategy of road owners that refuse to share the risk associated with innovations and still perform the business as usual model, which clearly divides between the government rights and the contractor's duties and tasks. This factor indicates the stalemate in changes of social views on new technologies for the regime shift signs.

As the COVID-19 pandemic hit the economy hard, the virus also hit the development of Bioasphalt as several ambitious projects for testing the materials were delayed. At the same time, the drop in the price of bitumen reflected negatively on the price of biobased asphalt, which is already estimated at 20% higher than the bitumen-based counterpart.

The Rijkswaterstaat being a large organization, actors of different categories have struggled to get it involved in their Bioasphalt demonstrations expect for the CBBD management, which happened by chance. Several actors had talks with RWS but with different departments in the ministry and no success. This shows the degree of fragmentation inside the Rijkswaterstaat, which forms another barrier for the development of this innovative technology. On the other hand, the size of the contractors advocating for this technology is an advantage, combined with their motivation for a sustainable transition SMEs are able to take quick decisions and adapt to the market demands in a swift manner.

4.4.1.h.2. Political and Regulative Factors

<u>Indicator</u>*: Absence of Biobased policies.*

In the Dutch Climate Agreement (Rijksoverheid, 2019), the government shows intentions to develop and support the biobased economy however, until this moment there is no holistic strategy guiding Bioasphalt or biobased products except for biomass which is taking central stage in all publications related to biobased economy. Prior to this agreement, TKI (2015) has developed a research agenda for twelve years, which resonated with the first realization of demonstration project for Bioasphalt. While the ingredients for a robust bioeconomy are there, the coordination of projects and vision alignment appears to be missing. Two experts from two different categories have confirmed the absence of a holistic strategy by the Dutch government to support biobased products.

4.4.1.h.3. Demand Factors

<u>Indicators</u>*: Lack of knowledge from road owners on Bioasphalt; Price of Bioasphalt; Trust in innovations; Uncertainty of innovation.*

Several road owners are reluctant to experiment with Bioasphalt on their roads. The above indicators are clear reasons why Bioasphalt may appeal to them but they will not use it. As a new technology, road owners do not have enough knowledge about it, which puts a lot of pressure on the innovators to prove that their innovation is up to market standards (basing these standards on the bitumen-based asphalt performance). For that reason, innovators are always met with a series of questions about performance, durability, lifetime, etc. This stresses on the classic dilemma of mistrust in new technologies and the uncertainty that accompanies such processes, which are typical features of new technological innovations. Actors react to this by building up their knowledge and experience through gathering as much data from the demonstration roads as possible to promote the technology for road owners.

4.4.1.h.4. Social, Cultural, and Behavioral Factors

<u>Indicators</u>*: Trust in the government/Rijkswaterstaat; Culture of sustainability.*

Two interviewees expressed their mistrust in the way RWS is conducting business. This mistrust is based on their experience in different situations referring to the changes in regulation. Therefore, smaller road owners are reluctant to incorporate Bioasphalt for the fear that the Rijkswaterstaat may change asphalt standards later, based on the previous changes in asphalt standards for the European standards in 2003-2005, and the recent changes in circular procurements. When trying to triangulate this indicator with other interviewees, they negatively responded claiming no experience on the issue.

4.4.1.h.5. Natural Environment Factors

Indicators*: Conflict in Land Use; Environmental pollution.*

In biobased products, the conflict between land for food and land for energy is common. This could influence the development of biobased innovation directly, but in the case of Bioasphalt, the impact is indirect. Although the raw material used in Bioasphalt is a by-product of the pulp industry, tracing the origins of the raw material may reveal this conflict, which will remain an issue for the LCA of Bioasphalt. The CHAPLIN-XL project is working on improving the LCA and investigating this conflict further.

4.4.2. Regime shifts in the bioeconomy context

The overview of the case study provided at the beginning of this chapter along with the analysis of the factors above can give us insights on the asphalt system. Obviously, the bond between the macro and meso levels of the system is robust, and the domination of the macro level is evident. The government being the regulator and the market from one side, and the development of oil refining companies that lead to their apathy towards bitumen production on the other side show that the system structure exists mainly in the macro level.

In the case of Bioasphalt, the regime shifts refer to the changes in the bitumen-based asphalt industry and related government bodies that represent the market and the legislation. Here the bitumen asphalt industry is facing major disruption in the bitumen supply, meaning that these regime shifts are mostly a result of the global changes on the macro-level but not because of the development in the micro-level of the sociotechnical system. At the same time, the data collected from the empirical situation revealed that the effect of the above factors on the meso-level is almost negligible, which confirms the underdevelopment of the biobased technologies. Therefore, in order to provide a comprehensive answer to the second and third research sub-questions, we look at the following signs of change along with the system subcomponents interactions as they are closely related.

4.4.2.a. Interrelations between technological progress and the social and managerial environment

Indicators: *Existence of large companies in niche (vested interests); Incubation of innovation by incumbent regime large companies; Perception of increasing demand for new technology; Perception of the agreement on the efficiency of conventional technologies; Formation of new regulations and policies regarding innovation.*

The cultural shift to sustainability and environmental preservation in the last few decades has altered the perception of road owners, asphalt companies, and knowledge institutions to seek green alternatives to fossil fuels. Currently, the main demand for new technologies in the asphalt sector is focused on recycling old asphalt as much as possible. The general acceptance of bitumen-based asphalt regardless of it damaging impact on the environment did not prevent some road owners from believing in the biobased options.

This shift in perception of demand for Bioasphalt can partially be attributed to the realization of demonstration projects that allowed for second learning orders like learning by doing, and awareness of diverse resources. Consequently, the outcome of this learning process has resulted in improving the technical aspects hence, better promotion of the technology to road owners. The best examples of this cycle are in Noord Holland Province plan to replace all bitumen roads with lignin material, and the realization of other test sections across the Netherlands.

However, this trust in Bioasphalt is not shared among potential investors and road owners; it is fable to the extent that vested-interests from large companies are barely existent. Nevertheless, the involvement of these large companies in the network may offer essential resources needed for the development of the technology, the only company present in this consortium that used to produce bitumen is a large Kuwaiti oil company that stopped producing bitumen on the Dutch soil. This company has its own research laboratory and team in the Netherlands still functioning and cooperating in this network by offering their knowledge of bitumen as well as grants for PhD research in the field of bitumen and lignin to TU Delft students. It remains unclear to which degree their interest in lignin-based asphalt is except for marketing, therefore the question is what will be the role of this company when bitumen is fully replaced with lignin?

This negligible interest form large companies could be a reflection of three explanations. First, the inability of the network, mainly the transition broker, to bring the attention of large companies to the technology, and second is related to the inherent features of underdevelopment of niche innovation, and its inability to prove its investment value. A third interpretation may stem from the shift in the oil refining industry, which prioritizes the high-end chemicals market and undermines the asphalt market.

On the same argument, one respondent referred to the effect of the market instability and the underdevelopment of the technology on the required shift of investments in infrastructure for asphalt plants from bitumen to lignin, which resonates with the second and third explanations.

4.4.2.b. Specialized Applications in the early stage of development

Indicator: *Appearance of new specialized applications within the bitumen industry.*

Most interviewees agreed that the substantial recent changes in the bitumen-based asphalt is the increasing percentage of recyclable asphalt. The higher the percentage is, the likely the contractor will win a tender from road owners. By looking at the roots of this issue, we can understand the reasons behind it:

a. The move towards a circular economy has encouraged the Rijkswaterstaat and local governments to favor recycled asphalt to overcome the shortage of bitumen and to foster their circular economy profiling,
b. The Netherlands is a leader in recycling old roads for decade. Therefore, the recycling techniques, road performance, and all related technicalities are not a novelty to the Dutch market,
c. The reduction in the amount of bitumen produced as well as its quality has pushed for more recycling of old roads.

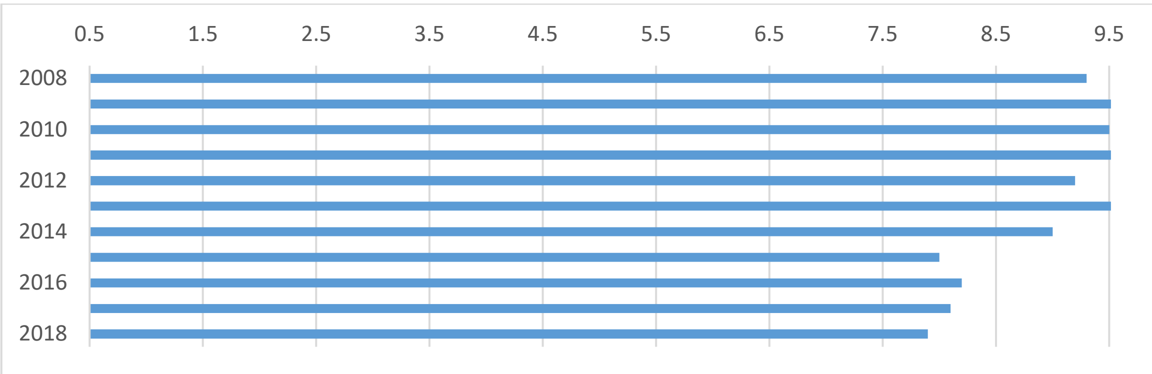
4.4.2.c. Related techniques

Indicator: *Disruption in incumbent technology's supply chain*.

The main difference between lignin-based and bitumen-based asphalt is the only binder, yet other ingredients remain the same. Respondents agreed on no disruption in all the asphalt components expect for the bitumen. While this disruption is the main driver for actors to seek the bio rival, the urgency factor to push for a bio option appears to be unrealized. Despite this reduction in bitumen, most road owners until recently only focus on the road performance and technicality without considering the full material cycle. Positive externalities has contributed to this, mainly the price drop in fossil fuel due to the COVID-19 pandemic, the demand for more refining of oil, and the depleting fossil resources.

> *"The same story about the quality. What I know is that it's also about the reliability of getting the bitumen, I know there is one supplier who drove their own trucks to get the bitumen from France, because there's a refinery there. That's one example but I think it's a global market, the industry is continuously looking for alternatives." C3*

Figure 10: Bitumen imports in the Netherlands.



Production of Bitumen in the Netherlands in million tons is in decline since 2013 (EAPA, 2020).

4.4.2.d. Social views on the new technology

Indicators: *Change of perception of Bioasphalt among different actors in the last ten years; Changes of vision and structure in the incumbent regime.*

The closing of old refineries and refraining from bitumen production by oil companies has led to anticipated changes. All interviewees and experts perception on the changes in the vision and structure of the bitumen industry is based on the material supply shortage. Meanwhile, their answers revealed a large gap between the innovation and the bitumen producing companies or oil companies in general. Equally, there was no clear evidence of any changes in asphalt construction companies except for the intense focus on reclaiming bitumen from old roads.

Nonetheless, two visible changes on the road owners side; the first is in Noord Holland Province (which is not part of the CBBD) and their plans to support the demonstration projects in order to fulfil parts of its carbon reduction goals through biobased asphalt. The second is in the structural changes inside the Rijkswaterstaat that allowed for hiring an expert to look after biobased solutions for the national roads. Although these changes may seem insignificant, they might be the spark for further structural changes in the market and the governments since they appeared on the macro-level, and can lead to a rippling effect if actors used this small window of opportunity.

On the other hand, the recent plans by the Dutch government to introduce carbon tax may have a positive contribution to push for biobased innovation, albeit the delay because of COVID-19 (DN, 2020). By taxing polluting industries like bitumen-based asphalt, the perception of demand for cleaner technologies may increase.

4.4.3. The interdependencies among the factors affecting the development of innovation

In order to provide an answer for the third sub-question, we look at the factors mentioned above and their interactions with the three levels of the sociotechnical system. The co-occurrences feature in Atlas.ti renders the relationships in terms of numbers in a double matrix, which is shown in the table below (Table 4). The higher the number, the likelihood of interaction between both variables. Although the table does not show all mechanisms between the factors, 353 quotes were carefully examined to understand the relationships between variables.

Table 4: Co-occurrences table

		SNM			MLP-TM				MLP-RS			
		• Learning Processes	• Shaping Expectations	• Social Networking	• Economic & Financial Factor	• Infrastructure & Maintenance	• Policies & Regulations	• Technical	• Interrelations between Tech-Socio-Management	• Related Techniques	• Social Views	• Specialized Apps
SNM	• Learning Processes	0	19	25	13	4	6	14	5	2	5	0
	• Shaping Expectations	19	0	32	10	10	9	23	6	0	5	0
	• Social Networking	25	32	0	10	11	5	23	4	0	6	2
TM-MLP	• Economic & Financial Factor	13	10	10	0	0	3	16	2	1	2	0
	• Infrastructure & Maintenance	4	10	11	0	0	8	6	7	0	6	1
	• Policies & Regulations	6	9	5	3	8	0	3	8	0	4	0
	• Technical	14	23	23	16	6	3	0	8	1	4	2
TM-RS	• Interrelations between Tech-Socio-Management	5	6	4	2	7	8	8	0	5	9	6
	• Related Techniques	2	0	0	1	0	0	1	5	0	4	5
	• Social Views	5	5	6	2	6	4	4	9	4	0	5
	• Specialized Apps	0	0	2	0	1	0	2	6	5	5	0

Co-occurrences table showing the number of quotes intersecting between the variables. Source: The author.

Each cell represents the number of intersecting quotes related to the variables showing a relationship. From this table, we can observe that most of the interactions (highest numbers) are at the micro-micro level, and the most dynamic relationship is between social networking and shaping expectations. This relationship can explain the main strategy the network's actors are using to generate resources for the development of Bioasphalt.

The second most important interactions were between the three processes of the nurturing mechanisms but with the technical factors, which draws a picture of an underdeveloped innovation seeking resources to focus on improving its technical performance (micro-macro level). Meanwhile, the least interactions are between the innovation and the incumbent regime (micro-meso level) which confirms that the innovation is still in a developing stage and its effect on the regime is yet unobserved. Below the table, a further explanation to these interactions is provided and discussed.

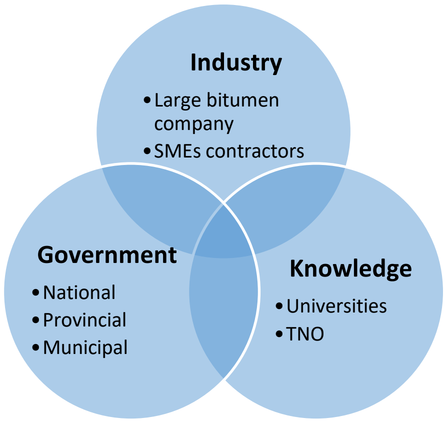
4.4.3.a. Micro-Micro interactions

The most powerful relationship between indicators is between Social Networking and Shaping of Expectations. The CBBD has endorsed these expectations through stimulating the cooperation, gathering information on market and users, and spanning the boundaries of this cooperation. The strong willingness from all actors to support the technology is a result of these mechanisms being reflected in their experimentations and plans for further developments. Although the mission for the CHAPLIN program is revolving around reduction of CO_2 emissions to match the superior goal of CBBD, the specific goals for the technology are still missing.

The second most powerful relation is between Social Networking and Learning Processes. The CHAPLIN program was created through social networking by the CBBD to connect stakeholders along the value chain to share resources. This strategy aimed at shaping the expectations of actors, which is the main ingredient to reach for more knowledge, and development of the technology. While the stakeholders are not part of the CBBD, and each of them already have their own networks, the interdependencies between them remains elevated (Figure 11). The contractors rely on WUR and TNO for developing the material properties, Utrecht University for the LCA development of Lignin, Q8 Research for its laboratories and knowledge of bitumen, and the CBBD for the promotion and marketing of the project with governments. Evidently, actors have used their networking skills to secure first and second-order learning, which is crucial in developing the technology and market competition.

> *"The CHAPLIN doesn't offer infrastructure because all the participants have the infrastructure and then through the collaboration, we made that available. And we do help organize brands so we don't have the money ourselves but friends within the CHAPLIN program. We now have two projects running that are supported by grants from the Dutch government." C2*

Figure 11: The CHAPLIN Program triple helix.

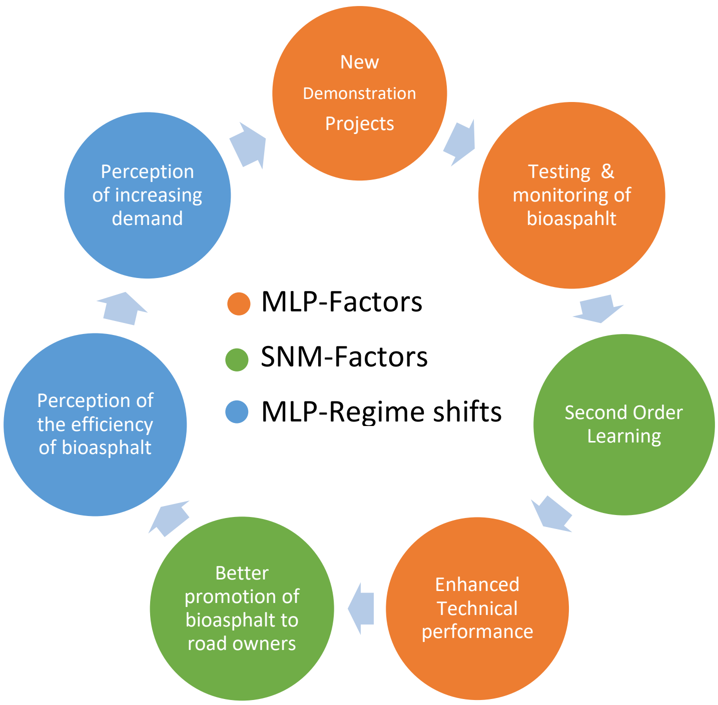


Types of actors in the CHAPLIN program network (the triple helix). Source: The author.

4.4.3.b. Micro-Macro interactions

The previous social networking strategy has resulted in interactions with the macro-level, mainly in the technical part. By generating resources and shaping expectations in the micro-level, actors were able to interact with the road owners and realize several demonstration projects. At the same time, the involvement of road owners has expanded their networks and that shows the strong relationship between the technical factors and social networking (Figure 12). Although the expectations are not shared with the Rijkswaterstaat yet, but only recently they managed to involve them in the cooperation hoping to align them with the Bioasphalt experimentations.

Figure 12: Perception change process in Bioasphalt.



The importance of second order learning processes in the realization of new demonstration projects that lead to changing the perception of the technology.

While the impact of the economic factors on social networking is mostly negative, it is good to mention that the availability of lignin in the international market has allowed for the demonstration projects to take place, and for actors to test their materials. On the other hand, the policies and regulations that were initially created for the bitumen-based asphalt are unjust towards lignin-based. The governance of procurement and project management inside the governmental bodies has prevented the rapid development of this technology. According to several actors, procurement is based on performance, price, and lifespan without any risk-sharing from the road owner side regardless of mechanisms like the *Innovatiegericht Inkopen* for innovation procurement. At the same time, reluctance from project managers to use an underdeveloped bio product and favor other techniques like recycled asphalt because of the time limitation nature of projects, and their strong knowledge in bitumen is preventing Bioasphalt contractors from winning tenders.

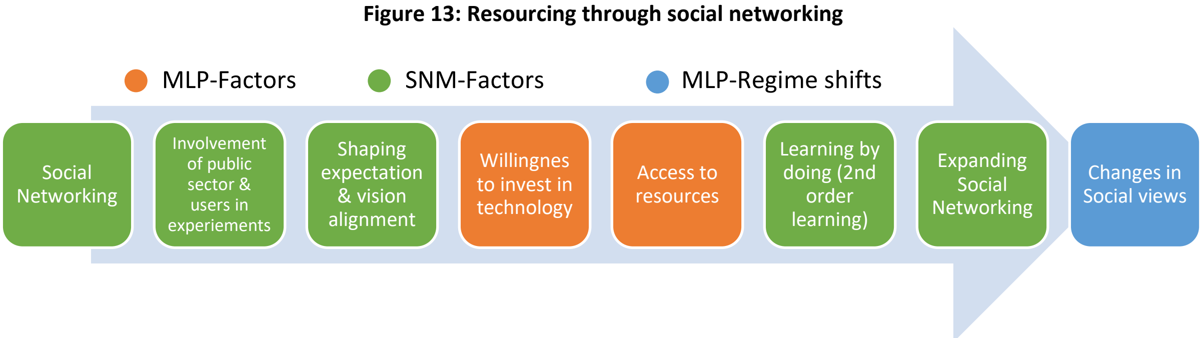
On a bigger scale, the hype around the circular economy and the government strategy for 2030 has influenced road owners' choices during procurements. They would favor a tried and tested product over bio products because of their limited timeframe until 2030.

The fragmentation of the Rijkswaterstaat and the different systems of each municipality and province have also influenced the innovation in different ways. Innovators have to network more, and use several networking techniques to reach for road owners who are willing to be involved. Several participants have relations with different departments in the Rijkswaterstaat but the latter is not yet involved.

> *"I'm always looking on websites of municipalities or companies.. they say that we are sustainable, we have special demands for sustainability. And sometimes it's true, sometimes it's a bit of a marketing issue, so you have to find out that. But at this moment there is nothing on national level for Bioasphalt."*

Material availability in the case of Bioasphalt is a major factor. The main driver here is the disruption in bitumen supply. At the same time, the lignin availability in the Netherlands is still limited and of low quality, which has opened international markets and new networks allowing for demonstrations beyond the boundaries of the Dutch system.

Figure 13: Resourcing through social networking



Using social networking to generate resources and influence the changes in social views about new technologies. Source: The Author.

4.4.3.c. Micro-Meso interactions

As stated above, the interactions between the micro and meso levels are minimal at this stage of development. Changes in perception of the need for new technologies has already existed before the invention of lignin-based asphalt in the form of recycled-asphalt. The Netherlands is a leader in the recycling of asphalt for decades, but not because of the shortage of bitumen rather for the culture of sustainability and recycling. In addition, the need for reclaiming more bitumen from old roads is increasing and the higher the percentage of recycled asphalt the more it appeals to road owners to satisfy their sustainability goals. While this demand for new technology is stable, the curiosity from road owners is increasing, and actors are using their knowledge of the potentials of lignin combined with the results of demonstration projects to lure governments for collaboration in experiments.

4.4.3.d. The Transition Intermediary

Being the transition broker, the effectiveness of the mechanisms used by the CBBD to steer the innovation in Bioasphalt remains under question. The CBBD vision to develop the technology is to promote it among actors outside the network. At the same time, it focuses on stimulating cooperation inside the network, while the expansion of the network is taking one direction: towards road owners only (market). These mechanisms are; dissemination of newsletters that include the development on all fronts; and the CHAPLIN Expedition Day which is aimed at creating personal connection and sharing information among actors. In contrast, three other interviews rendered the CBBD policies as ineffective except for marketing and promotion of the technology, which means that the CBBD can be identified as a user intermediary that is concerned with only translating the technology to the users (the government in this case).

Not only do actors in the network seem to have specific tasks without general agreement on their expectations out of the experiments, they also have different plans concerning the development of the technology. Although there is coordination between them to perform these tasks but the lack of vision and specific goals mentioned above create a mismatch and renders the structuralization of the network as weak. Some actors believe that by establishing a niche market among municipalities, it will be easier to develop and access the national roads market. Other actors believe that they should address the national roads to gain more experience. Nevertheless, their general vision is:

> *"There's no specific plan for Bioasphalt because that's a new development. But it's one of the developments that supports CO2 reduction and the change from fossil to circular and biobased."C2*

From a governance point of view, it is obvious that this biobased technology cannot access markets without the involvement of all related actors, and mainly the government. In the case of Bioasphalt, the government can steer the development of the technology by removing barriers to the market. The role of the transition broker here is essential to bridge the gap between the government and the innovation to allow for the removal of these obstacles. Although progress on this front is moderate, no clear targets are assigned for such involvement, which stalemates the development of the technology, and risks losing a valuable opportunity to create regime changes. Internally, not all the network actors are aligned with the broker's plans for development. Some of the respondents expressed their dissatisfaction with the CBBD strategy in managing the network and described it as *overly controlling*. Consequently, this internal strategy has resulted in a fragmented network and created a:

a. Repulsive effect; not all actors are sharing the same goals of the technology and working together only out of their obligation to the network with little motivation for cooperation,
b. Unshared expectations; actors unwillingness to fully share resources apart from the 'assigned tasks,'
c. Lack of synergy; as a result of the above, actors are working in different directions and relying on their own sub-networks which undermines their effort.

Chapter 5: Conclusion and recommendation

5.1. Research purpose and discussion

The main research objective is to understand the bioeconomy transition management in the Netherlands through analyzing the interactions between niche innovation and the other sociotechnical system components. While theoretically test the applicability of the MLP theoretical framework on biobased innovation. For this reason, the lignin-based asphalt was selected as the niche innovation case study where it thrives in the CHAPLIN program network. The latter is one of the programs in the triple helix organization, Circular Biobased Delta, which is a regional cooperation between governments, knowledge institutions, and business. Bioasphalt is an innovative response to the market disruption in bitumen supply with an aim to displace bitumen with lignin in the asphalt mix. Lignin on the other hand, is a biomaterial abundantly available in the global market yet the amount of Dutch lignin is not enough to allow for bio roads, while the CHAPLIN program is also looking for solutions to maximize the use of the Dutch lignin.

Theoretically, the tension between the regime and the landscape would open a window for innovations to breakthrough and force a regime shift towards a sustainable path. Empirically, this is not the case in Bioasphalt. There is a minimal traction between the innovation and the bitumen industry as the landscape has primarily endorsed the regime to prevent its collapse and disabled bio innovation from creating systemic changes. The main driver for the regime shift is the lack of the raw material essential for the incumbent industry; bitumen. The macro-level presented here by the policies, regulations, procurements, governance, and cultural norms have worked together to ensure the survival of the bitumen-based industry and avoid the system collapse for as long as possible. At the same time, the meso-level presented by the bitumen-based industry has improved its application in recycling and reclaiming bitumen from old roads to weather the disruption in its supply chain. This move by the industrial landscape and regime has formed the main barriers for innovation in the lignin-based asphalt.

Technically, there are fifteen demonstration projects around the Netherlands with the oldest of them dating back to 2015 however; this is not enough to develop a robust technology that can prove its rival performance against the well-established regular asphalt. The road lifespan, which ranges from ten to fifteen years, plays a crucial role in the transition. From the road owners' point of view, a five years experiment is not enough to prove performance conformity at a time when they want to reach 50% circularity by 2030.

This circular economy strategy has indirectly affected biobased innovation negatively as the same road owners would favor the incumbent regime solution (recycled asphalt) because it matches their regulations, standards, and their staff have gained experience in it. At a time when all the government levels are working on the clock to meet the national circular economy targets, giving time and investments to new underdeveloped bio solutions appears to be a luxury that road owners do not afford, and a risk they will not take regardless of the benefits that Bioasphalt may render in the future for the same targets.

The Bioasphalt is in the development stage of TRL 7 and requires further optimization along its value chain in order to conform to the current asphalt standards challenges. While many experts use the Technological Readiness Levels to measure the development of a technology, it is advantageous for the multiphase framework to incorporate the TRL indicator to pinpoint thresholds for phase changes in the bioeconomy transition. However, TRL cannot solely indicate changes but, a precise study of the potential markets where the technology should exist in along with visible institutional reforms should also be another indicator albeit the sensitivity to the innovation typology. This case study is an example; the changes in the structure of the Rijkswaterstaat to support Bioasphalt can be an indicator of the shift from a predevelopment phase to a take-off phase, because these structural changes allowed for demonstrations on the national highways, which is an important market that Bioasphalt strives to access. Consequently, actors can generate more knowledge on lignin use in asphalt and improve Bioasphalt TRL, which will unlock further potential markets and allow for disseminating the technology.

On another front, the advocates across the value chain of Bioasphalt have relied on creating networks through social networking among their own networks to harvest resources and gain the essential support to break through the industry's landscape. Meanwhile, the CBBD worked as an intermediary between innovation and the government to promote the technology and expand the Bioasphalt network to include the national government. However, the mechanisms used by the CBBD are not able to create a cohesive network with bold targets. Agents in the Bioasphalt network, including the transition broker, do not share the same expectations of the technology, nor a vision or targets. Each of them have their own plans for developing Bioasphalt, which created a fragmented and fragile network. Both the factors that exist in the sociotechnical system and the governance of the technology at the micro-level have contributed to the deceleration of the biobased product development.

5.2. Conclusion

From the previous analysis and theoretical framework, it is safe to conclude that the MLP-SNM framework is applicable to use for understanding the factors affecting the development of biobased niche innovation and the impact on the bioeconomy, albeit its shortcomings. It allowed for a holistic view of the bioeconomy transition management in the Netherlands rather this view lacks the sensitivity to empirical details. The framework is also useful to identify the static factors that contribute to the structure of the sociotechnical system, which assists policymakers in prioritizing interventions for developing biobased innovations.

On the other hand, the lack of specific indicators for technology development as well as the inattention to the agents' roles and their strategies to steer the innovation process renders the framework obsolete when applying it on entrepreneurs and small-scale technologies. Most of the literature for MLP-SNM was created during the first decade of the twenty-first century and lack the suitability for contemporary developments. Although social networking is at the heart of the SNM but it has largely ignored the role of intermediary agents, which is essential for linking between the systems' components.

The main hypothesis of the framework is that the landscape developments will open a window of opportunity for the niche, if seized, so regime changes will occur. However, it does not explain when the traction between the niche and the landscape is higher than the former with the regime, especially when the development on the regime level has opened a window of opportunity for niche creating systemic changes in the landscape. These dynamics require a revision for the MLP framework interactions as well.

Which sociotechnical system factors explain the development of biobased niche innovation in the asphalt industry, and how do these factors affect the regime shifts in the Dutch bioeconomy transition?

Several factors have affected the development of biobased niche innovation, these factors can stimulate and stagnate the development process. The Dutch plan for 2030 circularity has pushed the national and local governments towards sustainability and investigating the material resources across the value chains, which allowed for exploring bio alternatives. However, the sense of urgency to apply these plans has reflected negatively on bio innovations that strive for a market to test and develop. Users would favor a mature product to meet their targets swiftly and would not risk applying new solutions, as in the case of Bioasphalt. In the meantime, the current standards, regulations, norms, and policies are based on the incumbent regime, which was established decades ago on fossil industry performance norms. Indicators like the LCA or MKI, although proved to be effective in measuring the impact of a product or a technology on the environment, they offered little justice to the bioeconomy. Biobased products will perform worse against fossil-based products due to the biogenic carbon or emissions weighting methodologies, which are still under question and discussion. Valuing carbon sequestration or weighting the environmental impact through economic values requires changes in the methodologies of MKI and LCA assessments to ensure the standardization of environmental impact norms across different products.

This package affects the applications of bio products, as they do not conform to the current standards, creating further conflicts in certifying these products, market distancing, and inconformity. These policies should address procurements as well; although the strategic procurement plans have given a marginal space for innovation to grow through the MVI or *innovatiegericht inkopen*, the governance of procurement still largely depends on the clear division between government and labor, which extends to the project execution phase as well. The technical specifications of new technologies are always under the scrutiny of procurement managers. Uncertainty and underdevelopment of innovation is the classical dilemma in this vicious circle; applying the technology will allow for improving it or technology should be fully developed before being applicable. Innovations require a risk-sharing mechanism, which is usually missing from the consumer’s procurement policy.

According to literature, the existence of large companies in the innovation network may stagnate its development. Nevertheless, these stakes may not appear during the early phase of the formation of innovation. On the other hand, shaping of expectations while involving large companies in the network formation can generate resources and speed up the development. Hence, the role of transition brokers is crucial to the development of new innovative technologies because they align the expectations of technology between different actors. The neutral intentions of the intermediary agent can positively steer the development however, without mutual agreements and shared goals between both ends of the link, it can be an obstacle for the innovation progress.

Social networking is an essential factor for the development of innovation. By bringing actors together under the same vision and targets, networking creates willingness among actors to invest and generates resources essential for the technology. Governance of the network plays a crucial role in the speed of development and promotion of technology in potential fronts. These social networking mechanisms lead to new experimentations that allow for the second-order learnings. Through learning by doing, innovators not only take their innovation from the lab to the real world, but also expand their network and build trust with consumers and other actors. It drives development in the technical aspects as well as the promotion of technology in the market.

Furthermore, disruption in the supply chain of the incumbent regime industry is a major driver to innovate for alternative resources, at the same time, nature can offer more environmental friendly solutions. The timely intersection of both factors could push innovation forward if innovators directed the promotion of their bio products towards changing the cultural and social views on the efficiency of the incumbent industry.

The above findings demonstrate that regime changes are not necessarily due to the development of niche innovation or pressure from the industry landscape. Ultimately, the regulative, cognitive, and normative aspects that exist in both the meso and macro levels have kept the regime stabilized regardless of the major disruption in material supply. Specialized applications may give the system a longer lifetime too, but the developments on the complementary industries of the regime may potentially force systemic changes and open the window for radical innovation.

The Dutch government has used several instruments to stimulate its economy and the adoption of biobased products but at the same time, the absence of an integrational strategy with specific plans to coordinate and synergize between projects and programs is what derails the development of the biobased innovation. Six years after the *PBL* report[4] on the Dutch bioeconomy, and this research is confirming the findings from their report along with the other criticism mentioned in the first chapter. This slow pace of development is attributed to the interdependencies between the above factors, along with the lack of urgency related to the biobased case.

Access to capital and funds is available to innovators through grants or subsidies, which is manifested in the approval of two RVO grants to the CHAPLIN program and the demonstration projects like in Zeeland[5]. Small and medium enterprises however, were against green-innovation loans programs offered by the government as these loans pose a higher financial risk. SMEs are usually the frontrunners in innovation due to their motivation for taking a share in the market and their minimal structure, which allow for flexibility and faster decision-making. Therefore, they adapt to governance and are active in networking to generate resources nevertheless, sustainable financial models are required along with the subsidies and grants.

The development process is not in one direction but cyclical and iterative, it is more complex, and the interdependencies between its components are high. Hence, the transition pathway for the asphalt industry cannot be predicted, but the process can be stimulated and directed towards the most sustainable solutions available if the technology network is structured in a

[4] Hanemaaijer, A. H., Manders, A., Raspe, O., Berge, M. v. d., et al., 2014. Green gains: in search of opportunities for the Dutch economy. The Hague: PBL Netherlands Environmental Assessment Agency. Available at:
http://www.pbl.nl/en/publications/green-gains-in-search-of-opportunities-for-the-dutch-economy [Accessed 01-04-2020].

[5] The Zeeland government covered 20% from the total cost of the project while the remaining amount was funded by the Ministry of Economic Affairs and Climate Policy, local governments, the companies and knowledge institutions involved. Project participants are WUR, AKC, H4A, Cargill, Zeeland Seaports (Kwant; Hamer, et al., 2018).

cooperative manner, while creating synergies between actors and expanding its boundaries to include other related agents.

5.3. Recommendations

On a macro level, the Dutch government has made several financial instruments available for the development of biobased innovation however, these catalysts must exist within a joint financial model that clearly defines and positions bioeconomy in the circular economy plans. An integrated policy that targets the innovation population (SMEs) to reduce their financial risks, and at the same time, oblige the government to share the risk would give more room for bio innovators to grow. Meanwhile, policies and regulations can be formulated through the involvement of the public sector in the formation phase of biobased innovations in order to shift the tension from the micro-macro levels to the micro-meso level. Decoupling the economy from fossil fuels requires updating the fossil-based quality standards to match the new greener technologies in the new economic model. These regulatory updates must be supplemented by capacity building programs for the government's technical staff who are working in road construction to allow for accommodating innovations and using greener materials.

On a micro level, the lack of coordination and weak structure of the innovation network may stagnate the development. Therefore, constantly stimulating coordination between actors towards specific targets may catalyze the process, and increase the willingness to support the technology. This requires sharing the same vision and restructuring the roles inside the niche to realign the expectations and drive innovation further.

Expanding the network to involve more users may increase their trust in the innovation, especially the government, which will reflect on the division of risk among all parties, and improved technicality, respectively. The shortage of bitumen supply will inevitably create a sense of urgency in the near future to seek alternatives; Bioasphalt innovation should seize this window of opportunity to fill the market gap with a robust greener substitute.

5.4. Recommendation for future research

This research focused on the factors affecting biobased niche innovation in the Dutch context using the MLP-SNM theoretical framework. Future research can benefit from the qualitative data collected, and combine it with elements from the TIS framework to render a more nuanced analysis of biobased innovation. Adding dynamic factors like social networking, resourcing, and ecosystem orchestration to analyze the whole innovation process will assist in creating an indicative analysis that provides an inclusive strategic guideline for developing biobased innovations.

Adding quantitative indicators like the TRL, MVI, and LCA to the theoretical framework of transition management may allow for semi-quantitative analysis regarding phase-change indicators. Such indicators the tender score in the procurement of biobased innovations; thus, this quantitative methodology will provide a clear perspective on the factors that affect market penetration of biobased materials.

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Annex 1: Case Study Protocol

6.1. Factors affecting the Development of Niche Innovation

Below is the original hybrid list of factors identified according to (Kemp; Schot, et al., 1998, Painuly, 2001) and Hoogma et al. (2002), which contained eight factors affecting the development of niche innovation:

Factors	Function
Demand Factors	User preferences, risk aversion, and willingness to pay for a new tech that does not fully meet their demands. New technology’s price remains largely unaffordable. Manufacturers’ misconception about user preferences being invariable
Production Factors	Low incentives for production of new technology. Development process tends to be risky and characterized with high cost. Investors are deterred by the fact that new technology are still underdeveloped (beta tech).
Economic and Financial Factors	Economic landscape, and global economic crises, or major events. Banks are reluctant to invest in risky projects, government offering subsides for R&D only, and no funding mechanisms for marketing of the new technology except internal means.
Technical Factors	Requirement of complementary technology for the innovation (supply shortage, expensive). Optimization of new tech for user needs because of being underdeveloped or expensive (low scale production). Consumers have not tested the Technology in large scale.
Social, Cultural, and Behavioral Factors	Cultural values and norms. Unfamiliarity of manufacturers/producers with the new technology and its relation to their customer’s needs (judgement of new technology against the incumbent technology) Rendering of bad image of new technology performance.
Policies and Regulations Factors	Absence of technology policy based on clear view of the future to guide tech developers, planners, and investors towards sustainability. Regulatory framework may be a barrier for the development of new technology, and opposition from some actors against new regulations.
Natural Environment Factors	Contest between food and fuel over land use. Cheap fuel may create a rebound effect, more mileage and consumption patterns. Availability of natural resources related to the production chain of new technology.
Infrastructure and Maintenance Factors	Adaptation to infrastructure, and new distribution system must be established Labor needs training for the new technology. Infrastructure and maintenance investments are characterized by threshold value (must reach a certain number to render profit) regardless of the need for the infrastructure from new technology since early development. Lobby from current infrastructure groups against new technology infrastructure. Sunk investments.

6.2. Description of indicators

6.2.1. Factors affecting the development of biobased niche innovation

Below is the list of indicators that were used for determining the factors affecting the development of biobased niche innovation on the Bioasphalt case study. A description of each indicator is provided with the number of quotes where this corresponding indicators is mentioned in the interviews. This number is obtained through Atlas.ti, and it does not necessarily indicate the importance of the indicator, but the frequency of use by interviewees.

Indicator		Description	Frequency
Economic and Financial Factors			**46**
1	Availability of raw materials	The amount of lignin available in the Dutch and global markets.	18
2	Percentage of renewable materials in the LCA	The amount of renewable materials used to produce 1 squared meter of Bioasphalt.	5
3	Taxation on profit compared to conventional technologies	Taxes on Bioasphalt profits compared to bitumen-based asphalt.	4
4	Ability to access international market	Bioasphalt access to the international market.	1
5	Ability to access capital/loans/bonds	Accessibility to financial instruments by actors in the Bioasphalt network.	4
6	Perception of financial instruments and subsidies availability	Perception of actors on the availability of financial means to fund their biobased innovation.	9
7	Ability to access capital at the formation phase	Availability of capital funds for initiating the Bioasphalt innovation.	5
Technical Factors			**64**
1	Access to knowledge	Cooperation with knowledge institutions to improve Bioasphalt technicality in the CBBD.	10
2	Knowledge of technology potentials	Awareness of actors on the potentiality and special features of the Bioasphalt innovation.	16
3	Technology testing	Ability of actors to test the technology on large-scale or conduct demonstration of road sections.	11
4	Availability of complementary technology	The extent of development in the lignin industry.	15
5	Involvement of knowledge institutions in technology formation	The number and variety of knowledge institutions that co-initiated the Bioasphalt innovation.	12
Policies and Regulations Factors			**23**
1	Regulatory restrictions	The extent to which regulations are restricting development of Bioasphalt.	17
2	Lobbying from incumbent industry players on regulations	Intensity of lobbying by bitumen-based asphalt contractors for keeping asphalt standards and regulations.	2
3	Bureaucracy	Degree to which bureaucracy is complicating the process of Bioasphalt certification.	4
Infrastructure and Maintenance Factors			**50**
1	Requirement for new infrastructure	Extent to which Bioasphalt requires changes in current infrastructure.	7
2	Willingness to invest in infrastructure for new technology	Willingness from actors to invest in new infrastructure for Bioasphalt.	10

3	Availability of spare parts	Cost and availability of spare parts for Bioasphalt infrastructure compared with the same for bitumen-based asphalt.	3
4	Access to training mechanisms	Availability of training programs for staff working in Bioasphalt innovation in the Dutch market.	1
5	Access to skilled labor	Availability of educated and skilled staff in different aspects of Bioasphalt.	2
6	Compliance with certification	Degree to which certification and compliance requires changes to adapt for new technologies.	23
7	Intensity of lobbying from incumbent industry against innovation	Degree of intensity of lobbying by bitumen-based asphalt industry players against the formation of Bioasphalt initiatives.	4
Shaping Expectations			**61**
1	Expectation of innovation and willingness to support it	Actors' expectations from Bioasphalt and willingness to support its development.	36
2	Effectiveness of niche space strategies to nurture innovation	Effectiveness of strategies used by the CBBD to support Bioasphalt.	21
3	Alignment between experiments and expectations	Degree to which experiments conducted for the Bioasphalt development are matching with actors' expectations.	17
4	Involvement of public sector in vision formation	Inclusion of the three levels of governments in shaping the vision for Bioasphalt.	20
Social Networking			**90**
1	Existence of supply chain user-producer in niche space	Membership of lignin companies in the CBBD.	15
2	Involvement of road owners during experimentation phase	Inclusion of the three levels of governments in demonstrations of road sections.	16
3	Experience of staff in management and organization, PR, and bio processes	Accumulated experience of persons working for the development of Bioasphalt across different domains.	24
4	Extent to which organization and coordination between actors in CBBD is developed	Degree to which coordination between actors in the Bioasphalt network is effective.	30
5	Involvement of conventional industry during the formation of innovation	Inclusion of bitumen-based asphalt players in formation phase of Bioasphalt.	5
Learning Processes			**99**
1	Awareness of market needs	Perception of actors about asphalt market trends	27
2	Future plans for development	Existence of future plans and steps of development for Bioasphalt	16
3	Marketing mechanisms	Use of targeted marketing and tailored services for the market needs.	11
4	Awareness of diverse resources and actors of the supply chain	Actors' awareness of the lignin producers in the Dutch market and internationally.	16
5	Existence of learning-by-doing, and learning by using mechanisms	Use of learning-by-doing techniques to develop Bioasphalt.	15
6	Changes of values, norms, goals, and interests	Variation of values and vision of actors during the development process of Bioasphalt.	14

6.2.2. Factors affecting the development of biobased niche innovation induced from the empirical research

List of indicators that were induced during the data collection for the case study. They are categorized according to the same categories mentioned in chapter two and at the beginning of this annex. A description of each indicator is provided with the number of quotes where this corresponding indicators is mentioned in the interviews. This number is obtained through Atlas.ti, and it does not necessarily indicate the importance of the indicator, but the frequency of use by interviewees.

Indicator		Description	Frequency
Economic Factors			**72**
1	Circular economy	An economy model shifting from linear production to cyclic in order to eliminate waste and minimize the exploitation of raw materials.	15
2	COVID-19	A pandemic of the coronavirus infectious disease in the respiratory system that caused shutting down of businesses and transportation around the world.	4
3	Fragmentation of the Rijkswaterstaat	The multiplicity of department and extreme decentralization inside the RWS.	11
4	Recyclable asphalt technology	Mining of bitumen in the old roads and reusing the material in new roads, it requires a percentage of fresh bitumen as well.	21
5	Reduced production of bitumen	The development of oil refining techniques to maximize profit has led to less production of bitumen.	24
6	Motivation of actors	Actors' willingness to experiment with new technology for both sustainability and profit.	5
7	SMEs	Small and Medium Enterprises that are independent with a small number of employees and minimal hierarchy.	2
Political and Regulative Factors			**2**
1	Absence of biobased policies	Lack of a multidimensional, multi-institutional integrated policy concerning the development of the biobased products.	2
Demand Factors			**37**
1	Lack of knowledge from road owners on Bioasphalt	Unfamiliarity of road owners about the potentials of lignin-based asphalt.	3
2	Price of Bioasphalt	The price of a square meter of lignin-based asphalt.	10
3	Trust in innovations	Confidence in innovation and risk sharing with new technology.	17
4	Uncertainty of innovation	New technology and innovations are associated with uncertainty on several levels for example technical, environmental, or economic.	7
Social, Cultural, and Behavioral Factors			**14**
1	Trust in the government/Rijkswaterstaat	Confidence in conducting business with the government.	7

2	Culture of sustainability	The embedded principals of sustainability in the culture norms and behavior of the society members.	7
Natural Environment Factors			**10**
1	Conflict in Land Use	Conflicting views about the land use policies (for food, or for energy).	2
2	Environmental pollution	Contamination of the biological environment that negatively affect its processes.	8

6.2.3. Regime Shifts

The below indicators were used for determining the signs of regime shifts in the asphalt sociotechnical system. A description of each indicator is provided with the number of quotes where this corresponding indicators is mentioned in the interviews. This number is obtained through Atlas.ti, and it does not necessarily indicate the importance of the indicator, but the frequency of use by interviewees.

	Indicator	Description	Frequency
Interrelations between technological progress and, the social and managerial environment			**36**
1	Existence of large companies in niche (vested interests)	The number of large companies in the new technology network and their function.	4
2	Incubation of innovation by incumbent regime large companies	Providing services to startups and innovators by large companies.	2
3	Perception of increasing demand for new technology	Perception of actors on the demand for new technology.	11
4	Perception of the agreement on efficiency of conventional technologies	Perception of actors on the efficiency of bitumen-based asphalt applications.	10
5	Formation of new regulations and policies regarding innovation	New policies, standards, or plans that support biobased innovations.	9
Specialized Applications in the early stage of development			**8**
1	Appearance of new specialized applications within the incumbent industry	Changes in the technology of bitumen-based companies that offer new competitive service to biobased	8
Related Techniques			**21**
1	Disruption in the incumbent technology's supply chain	Constant availability of bitumen and other materials used for the fossil-based roads.	21
Social views on the new technology			**25**
1	Change of perception of innovation among different actors in the last ten years.	Changes of perception of Bioasphalt among actors in the last decade.	15
2	Changes of vision and structure in the incumbent regime	Structural changes in the bitumen industry.	10

6.3. List of partners of the CHAPLIN Program

Table 5: Partners in the CHAPLIN Program according to the Factsheet – CHAPLIN Program produced by the CBBD.

	Partner	Category		Partner	Category
1	Rijkswaterstaat (department of Waterways and Public Works)	Government: National	**12**	Roelofs Groep	Asphalt Industry

Partner		Category	Partner		Category
2	South Holland	Government: Province	13	Vertoro	PPP
3	North Brabant	Government: Province	14	Avantium	Lignin Industry
4	Zeeland	Government: Province	15	Praj	Engineering Company
5	Gelderland	Government: Province	16	Boskalis	Construction Industry
6	Overijssel	Government: Province	17	Biondoil	Chemicals Industry
7	Bergen op Zoom	Government: Municipality	18	University of Utrecht	Knowledge Institution
8	Dura Vermeer	Asphalt Industry	19	Wageningen Food & Biobased Research	Knowledge Institution
9	H4A	Asphalt Industry	20	TNO	Knowledge Institution
10	NTP	Asphalt Industry	21	Q8 Research	Asphalt Industry/ Knowledge Institution
11	Latexfalt	Asphalt Industry	22	Asfalt Kennis Centrum	Asphalt Industry/ Knowledge Institution

6.3.a. CHAPLIN-TKI project

Financed by RVO, this project has received a humble grant of €454.382 under the TKI Biobased Economy scheme in 'Thermochemical and Catalytic Conversion Technologies'. This project aims at testing the suitability of Dutch lignin in asphalt, create the feasibility study for Bioasphalt, and monitor the current and future test sections. Eleven partners from different backgrounds form the consortium of this project, which is headed by Richard Gosselink from Wageningen Food and Biobased Research.

Table 6: Partners in the CHAPLIN-TKI project and their relative category.

Partner		Category	Partner		Category
1	Wageningen Food & Biobased Research	Knowledge Institution	7	Stichting Biobased Delta	PPP
2	Asfalt Kennis Centrum (AKC)	Asphalt Industry/ Knowledge Institution	8	TNO Earth, Life and Social Sciences	Knowledge Institution
3	Avantium Chemicals BV	Lignin Industry	9	Universiteit Utrecht	Knowledge Institution
4	Dura Vermeer Infra Participaties	Asphalt Industry	10	Vertoro	PPP
5	Latexfalt	Asphalt Industry	11	Zeeuws Vlaamse Asfalt Centrale (H4A)	Asphalt Industry
6	NTP	Asphalt Industry			

6.3.b. CHAPLIN-XL project

The XL in this project name stands for Extra Large, referring to the bigger grant received by this project also from RVO and amounting to € 1.459.920. Headed by Martin Junginger from Utrecht University, this project has several targets but mainly it aims at testing the lignin produced by Avantium in the top layer of asphalt, as well as improving the LCA in order to raise the readiness level of Bioasphalt to TRL 6, and full commercialization of the product.

Table 7: Partners in the CHAPLIN-XL project and their relative category.

	Partner	Category		Partner	Category
1	Wageningen Food & Biobased Research	Knowledge Institution	**5**	Stichting Biobased Delta	PPP
2	Asfalt Kennis Centrum (AKC)	Asphalt Industry/ Knowledge Institution	**6**	Universiteit Utrecht	Knowledge Institution
3	Avantium Chemicals BV	Lignin Industry	**7**	Roelofs Advies en Ontwerp	Asphalt Industry
4	H4A Infratechniek	Asphalt Industry	**8**	Roelofs Wegenbouw	Asphalt Industry

6.4. List of Respondents

Table 8: List of respondents

	Category	Source	Interview Duration
1	Entrepreneurs/construction companies/contractors (C1)	Desk research - LinkedIn	58:56
2	Entrepreneurs/construction companies/contractors (C1)	Snowball	101:21
3	CBBD Management (C2)	Snowball	44:30
4	Road Owners (C3)	Snowball	62:52
5	Road Owners (C3)	Desk research -LinkedIn	64:35
6	Incumbent Industry (C4)	Snowball	55:27
7	Knowledge institutions (C5)	Snowball	24:11
8	Knowledge institutions (C5)	Snowball	99:39
9	Knowledge institutions (C5)	Desk research	49:36
10	Knowledge institutions (C5)	Snowball	84:00
11	Knowledge institutions (C5)	Desk research	54:46

6.5. Key Interview Questions

A list of key interview question is provided in the below table. These questions were formulated during the data collection.

Table 9: Key interview questions

	Question	Category
1	If the Rijkswaterstaat want to propose new regulations, will they be biased towards bitumen?	Entrepreneurs/construction companies/contractors (C1)
2	Do you cooperate also with other lignin companies or Bioasphalt companies in order to push for changes in the industry?	
3	Do you think there are vested interests that you observe are possible in the CBBD region? In this network, do you also see lobbying against Bioasphalt or is it outside of the CBBD?	
4	Regarding the CHAPLIN program, do you monitor the progress of the program? Whether the parties or the actors are collaborating and doing something together? Or as a CBBD you don't get involved or actually steer more interaction inside the program?	CBBD Management (C2)
5	Apart from the depleting resources, what are other factors that are actually pushing the demand for Bioasphalt?	
6	Do you think that the current regulations, standards, and norms for asphalt are effective enough to stimulate innovation in biobased asphalt? Is there a need for changing some of these regulations or certification, or any norms and standards?	Road Owners (C3)

	Question	Category
7	Regarding your cooperation with the CBBD, do you have a specific targets for this cooperation?	
8	Do you anticipate changes in these standards or regulations in the coming years?	
9	Do you have a target with specific standards that you agreed with the contractors on? So once you reach these standards, they will become certified, or will you keep testing until you reach a new agreement?	
10	In terms of procurement, do you think there is a conflict between recyclable asphalt and biobased asphalt? Do you think road owners would prefer recycled asphalt to biobased?	
11	What do large companies such as yours offer to the lignin-based asphalt in the CBBD?	Incumbent Industry (C4)
12	Do you anticipate that the Bioasphalt in general whatever the technique is used will replace bitumen in the near or far future?	
13	How do you measure the success of an innovations? Do you need cooperation with other actors to achieve this success?	Knowledge Institutions (C5)
14	Do you think, in your perception, the CBBD strategy inside and outside this network are supporting enough?	

Annex 2: Research Instruments and Time schedule

6.6. Interview Protocol

The consent that the eleven interviewees have agreed on included the following points:

1. Personal information, contacts, and data are not part of this research and will not be shared or processed with anyone except the researcher involved in this thesis;

2. The interview is recorded and a transcript was produced and shared with the interviewee, and they were given the opportunity to correct any factual errors;

3. Access to the interview transcript is limited to the main research and academic colleagues and researchers with whom I might collaborate as part of this research process;

4. The actual recording were permanently erased after the transcript was approved, while the transcript files are digitally encrypted and kept in a local hard drive;

5. The information collected from interviews are processed using a Quantitative Data Analysis software and Fuzzy Cognitive Mapping in order to analyze the data for this thesis. Results of the research will be shared with interviewee upon graduation.

6.7. Initial Interview Key Questions

The following table includes some preliminary questions that were intended for use during the interviews with different actors; however they were changed after the second interview dependent on the development of the data collected during the interviews.

Table 10: Initial interview key questions

Actor	Question	Related Indicator
Conventional Industry	Do you think Bioasphalt may disrupt your supply chain?	Disruption in conventional tech supply chain.
Conventional Industry	Have you changed your R&D? Do you offer newly added specialized application? Changes in structure?	Appearance of new specialized applications within the conventional tech.
Conventional Industry	Which potentials do you see in Bioasphalt?	Knowledge of tech potentials
Industry in CBBD	Have you offered support to Bioasphalt in their formation stage? Why?	-Involvement of NGOs and users
Innovator	How much tax do you pay compared to conventional tech?	Taxation on profit compared to conventional technologies
Innovator	Do you have better access to bonds/loans now?	Ability to access capital/loans/bonds
Innovator	Are you aware of subsidies schemes?	Perception of financial instruments and subsidies availability
Innovator	Are you aware of (entity/NATgovt) subsidies schemes or CBBD grants?	Perception of financial instruments and subsidies availability
Innovator	How did you acquire the capital? Have you thought of other means?	Ability to access capital at the formation stage

Actor	Question	Related Indicator
Innovator	Are you willing to invest in infrastructure for Bioasphalt?	Willingness to invest in infrastructure of new tech
Innovator	Are spare parts available and cheap?	Cost and availability of spare parts compared to conventional tech
Knowledge Institutions	What are your expectations of Bioasphalt? Are you willing to offer support? And what kind of support do you offer?	CBBD actors expectations about tech and Willingness to support it
Knowledge Institutions	What was your perception of Bioasphalt before and now?	-Changes of vision and structure in conventional industries.
Knowledge Institutions	How do you measure success? Do you need also cooperation from other actors? Who are they?	Effectiveness of policies and regulations inside CBBD to support innovations

6.8. Timeline and actions

Table 11: Research timeline and actions

Timeline	Action
17-06-2020 – 11-07-2020	Data collection: Interviews, content analysis
12-07-2020 – 25-07-2020	Data Analysis: Data filtration, Atlas.ti processing
26-07-2020 – 06-08-2020	Draft report writing
06-08-2020 – 09-08-2020	Consultation with academic staff on research findings
August 10, 2020	First Draft Submission of Thesis
10-08-2020 – 17-08-2020	Case study report and database preparation
August 17, 2020	Feedback on first draft
18-08-2020 – 30-08-2020	Working on feedback from first submission
August 31, 2020	Final Submission of Thesis
September 7, 2020	Thesis defense

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