Exploring the 4th industrial revolution in relationship to the circular economy in Mid Brabant

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HZ University of Applied Sciences
Delta management graduation thesis (2020)
Midpoint Brabant Circular

Colophon

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Foreword

This explorative research about the relationship between data driven technologies and the circular economy in Mid Brabant is part of the graduation thesis. This graduation thesis is written for the bachelor Water management, specialising in Delta management. The research is conducted for Midpoint Brabant Circular, which is established in Tilburg, the Netherlands. Which data driven technologies are valuable for the circular economy in Mid Brabant? And, how can these technologies be implemented? These questions, asked in January 2020, were used as guidelines for conducting the research.

Today June 5th, 2020, the explorative research is finished. I feel privileged to have the opportunity to contribute to the circular hotspot Midpoint Brabant Circular.
I would like to thank Midpoint Brabant Circular and especially Herman Gels, for giving me the opportunity to conduct this graduation thesis. Also, I would like to thank Sarah de Bakker for her guidance during this process.

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Abstract

Our current linear economy works in the following system; take-make-waste. The waste products, materials and components contain lots of valuable resources that will end up on a landfill or being incinerated in order to generate energy. The majority of the companies in the research area Mid Brabant, are using the linear business model to conduct business. By changing their linear business model into a more sustainable and circular one, the companies will be contributing to a more sustainable Mid Brabant. The regional development company, Midpoint Brabant created a new entity to facilitate the transition from the linear economy a circular economy (CE), a company is called Midpoint Brabant Circular (MBC)

During the transition from a linear economy to a circular economy several problems will occur. These problems are often related to the transition of used business models, the circular models are characterized by take-make-reutilize instead of take-make-waste. For these problems, the entrepreneurs can visit MBC and ask for help. These problems can potentially be solved by technologies from the 4th industrial revolution. This potential is being explored in this qualitative research, with the following main question: *How can data driven technologies from the 4th industrial revolution contribute to the circular economy in Mid Brabant and Midpoint Brabant Circular?*

The method used is mostly desk research and due to Covid-19 less interviews were possible as expected.

The main results show, that the potential for a data economy is present in the province of North Brabant. The percentage of market share for North Brabant compared to the Netherlands is roughly 13%, this percentage is a significant share of the whole market. In the application areas of Midpoint Brabant are DALI, BioVoice, S4G, Gate2, Pitch logistics and Skills labs valuable projects as a source of information to build on. Other relevant organisations in Mid Brabant are MindLabs, Floow2 and JADS. These projects can be placed in the network of the data driven ecosystem in Mid Brabant. Other components of the data driven ecosystem are the platform and co evolution. The platform allows the actors in the network to contribute and use the data driven ecosystem. Floow2 can be a good partner for the development of the platform. Co-evolution is in the data driven ecosystem is necessary to achieve the full potential of the data economy.

Recommendations are formed for the application areas of Midpoint Brabant, these recommendations are presented in Chapter 6. The recommendations for MBC are; first, to take a leading role by implementing the technologies from the 4th industrial revolution for the CE. Second, the standardisation of data is essential for usage. Third, searching for students (JADS, Tilburg University, MindLabs) whom could execute the follow-up research. Last, organising the data driven ecosystem. The network needs to be established in collaboration with the applications areas of Midpoint. The platform (and dashboard) should be integrated in the portal (one-stop-stop) function. The co-evolution can be started with internal data sharing (between Midpoint application areas). When the internal data sharing is arranged properly, extend the data sharing with external quadruple helix organisations.

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Abbreviations

AI	: Artificial intelligence
BDA	: Big Data Analytics
CE	: Circular Economy
DALI	: Data sciences for Logistic Innovation
DDA	: Dutch Digital Alliance
ICT	: Information and Communication Technology
IoT	: Internet of Things
JADS	: Jheronimus Academy of Data Science
MBC	: Midpoint Brabant Circular
MOED	: Mid Brabant Developing company for Energy and Sustainability
PLM	: Product Lifecycle Management
RDBMS	: Relational Database Management Systems
RFID	: Radio Frequency Identification
SMA	: Strategic Multiple year Agenda
SME's	: Small and Medium Enterprises
S4G	: Symbiosis 4 Growth

1 Introduction

1.1 Background information

Transition to a circular economy

Our current linear economy works in the following system; take-make-waste. The waste products, materials and components, contain a lot of valuable resources that will end up on a landfill or incinerated in order to generate energy. However, these resources can be used again, if they are collected out of the waste products, materials and components. Our current consumption pattern already passed the limits of the earth. If the world's population lived like the inhabitants of the Netherlands, earth overshoot day would be on the 3th of May 2020 (appendix 1). "Earth overshoot day marks the date when humanity's demand for ecological resources and services in a given year exceeds what earth can regenerate in that year (Earth overshoot day. 2020)".

The above-mentioned problems of the linear economy can be changed by shifting to a more closed loop economy and a more responsible way of consuming. The circular economy (CE) is an industrial system that is restorative or regenerative by intention and design (Hobson. 2016), where closed loop production is implemented, with the main principle; "waste=food". However, implementing the CE is easier said than done. People are always tend to do what they have always done, but a change in mind-set is urgently needed. According to Moss Kanter (2012) facilitating change is hard, "We are creatures of habit. Routines become automatic, but change jolts us into consciousness, sometimes in uncomfortable ways. Too many differences can be distracting or confusing. Leaders should try to minimize the number of unrelated differences introduced by a central change. Wherever possible keep things familiar. Remain focused on the important things; avoid change for the sake of change".

4th industrial revolution

In the first two decades of the 21st century a lot of technological developments have taken place and are still taking place. These technological developments caused a new industrial revolution, which is called the 4th industrial revolution. The 4th industrial revolution gives society the opportunity to rearrange systems of the past, like the linear economy. The technologies from the 4th industrial revolution are driven by data; by collecting, analysing and integrating these data a lot of valuable information can be created.

Companies are facing challenges which holding them back to achieve their sustainability goals and the transition to a CE. These challenges can be solved by applying 4th industrial technologies in their circular business models and solutions (Rajput et al. 2019). According to the World Economic Forum (2019), the technologies from the 4th industrial revolution are helpful for implementing the CE.

Midpoint Brabant Circular

Midpoint Brabant Circular (MBC) (appendix 2) will be functioning as an accelerator, knowledge point, and a creative MakerSpace where companies can meet and develop ideas together. By concentrating the circular ideas and businesses, MBC can be one of those leaders that facilitate and participate in the mind-set change, which impacts the region and outside the boarders of the region.

Mid Brabant is an area located in the province North Brabant (figure 1). MBC is part of the mother company Midpoint Brabant and is established in Tilburg which is situated in the centre of Mid Brabant. Many companies are established in Mid Brabant, the majority of these companies are using the linear business model to do business. By changing their linear business model into a more sustainable and circular one, the companies will be contributing to a more sustainable Mid Brabant. Not only the companies should be contributing to the sustainable transition in Mid Brabant, but all the actors in the ecosystem. The used model to represent all actors in the ecosystem Mid Brabant is, the quadruple helix model of innovation. "The quadruple helix model of innovation recognizes four major actors in the innovation system: science, policy, industry and society (Schütz et al. 2019)". MBC wants to guide and facilitate this quadruple collaboration, in order to make Mid Brabant more sustainable and circular.

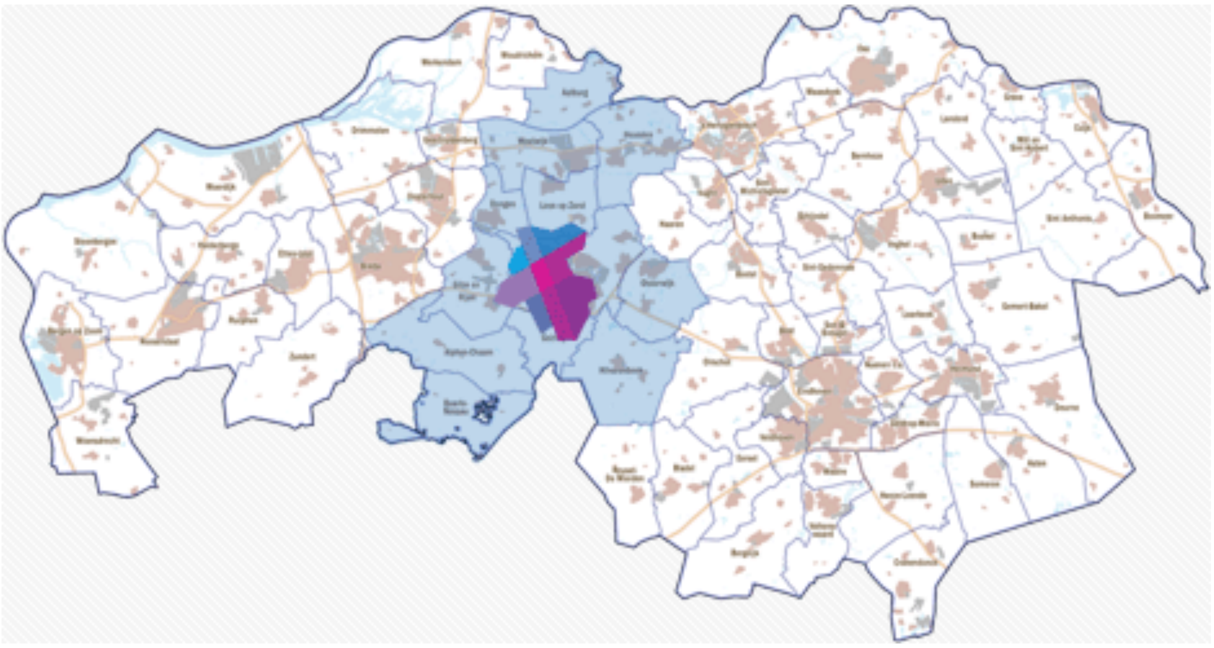


Figure 1. Mid Brabant. (WijZijnTilburg. 2018)

1.2 Problem statement

During the transition from a linear economy to a CE several problems occur. These problems are often related to the transition of used business models, the circular models are characterized by take-make-reutilize instead of take-make-waste. The reutilizing part is the difference, it will maximize the value of a product, material or component by keeping it in the loop of circularity. When the products, materials or components ending their lifecycle, they should be collected again and transferred to a facility where they are being remanufactured, reused or recycled (Upadhayay. 2019). This is easier said than done as circular business models such as reversed logistics, product as a service and the sharing platforms, are causing some practical issues for entrepreneurs. The entrepreneurs are lacking knowledge about the recyclability, reusability and re-manufacturability of their products. Moreover, another disadvantage is that circular products are often more expensive than linear products (Kas et al. 2017). For these issues, the entrepreneurs can visit MBC and ask for help.

The above-mentioned issues are holding the entrepreneurs back from achieving their sustainability goals and their transition to a CE. These issues can be solved by applying 4th industrial technologies in their circular business models and solutions (Rajput et al. 2019). MBC wants to apply these data driven technologies in the future in order to help the entrepreneurs the best as possible.

The technologies from the 4th industrial revolution are also capable of analysing real time data and interconnections within a certain area, in this case Mid Brabant. These interconnections can be used for planning, design and development. On the other hand, the data is a valuable raw resource for executing a more sustainable and circular approach within a certain area (Sukhdev et al. 2017).

However, MBC does not know which technologies from the 4th industrial revolution are helpful and how they are to apply them. This research is conducted to explore the possibilities of these technologies for both companies and the area Mid Brabant.

1.3 Objectives and research questions

Objectives

The objective of this research is to create recommendations as to which data driven technologies are helpful for implementing the CE in Mid Brabant. Because Midpoint Brabant already started implementing data driven technologies in their programmes, which are (in)direct connected with the CE, it is more than helpful to explore the possibilities for synergy. By combining the already used data driven technologies in the existing programmes and adding the "missed opportunities", an inclusive data driven ecosystem can be created around MBC. A data driven ecosystem can be best described as, "Data ecosystems are composed of complex networks of organisations and individuals that exchange and use data as main resource. Such ecosystems provide an environment for creating, managing and sustaining data sharing initiatives such as smart cities, open data and scientific data communities (Oliveira et al. 2018)". In this context, the data driven ecosystem is becoming an environment where quadruple helix organisations will exchange and use data in order to implement, facilitate and fasten the CE in Mid Brabant.

Research questions
The research questions are built up out of three main components; the CE, the 4th industrial revolution and a spatial component. The spatial component is represented by the ecosystem of Mid Brabant, with MBC in the centre. This ecosystem is being analysed and interventions are being proposed, in order to make Mid Brabant circular in a smart way. Technologies from the 4th industrial revolution are able to make connections within and out of the system Mid Brabant which are beyond human capacity. To create this explorative research, the following research questions are conducted.

How can data driven technologies from the 4th industrial revolution contribute to the circular economy in Mid Brabant and Midpoint Brabant Circular?

1. Which economic clusters, hubs and other relevant activities are present in the ecosystem of Mid Brabant?
2. Which data driven programmes from Midpoint Brabant, MOED and educational organisations can contribute and deliver synergy to Midpoint Brabant Circular?
3. How can be a data driven ecosystem created around Midpoint Brabant Circular?

1.4 Reading guide

The next chapter introduces the relevant literature and concepts, which is the theoretical basis for this research. In Chapter 3, the used methods are explained. In chapter 4 the results of the research are shown and in Chapter 5 these results are discussed. This explorative research will be finalized in Chapter 6 with the conclusions and recommendations.

2.0 Theoretical framework

2.1 Circular economy in the Netherlands and North Brabant

Circular Economy

"The CE has been defined as an industrial system that is restorative or regenerative by intention and design. It replaces the end-of-life concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse and return to the biosphere, and aims for the elimination of waste through the superior design of materials, products, systems and business models (Hobson. 2016)". Within the Netherlands there is a growing interest in the CE by businesses, governments and society. The main goal of the CE is to decouple economic value creation from resource consumption. The four values of the CE are summed up underneath:

1. Extending the use cycle length of an asset
2. Increasing utilisation of a product or a resource
3. Looping or cascading an asset through additional use cycles
4. Regeneration of natural capital
   (Ellen MacArthur foundation. 2016)

The systematic transition from the linear economy to the CE has a lot of impact on society. Our growth and prosperity are based on finite resources. However, before hitting the boundaries of these finite resources, our way of thinking has to change (Sauve et al. 2015). For example; remain the highest value of a product, material or component. The R-strategy is used to determine the highest value of a product (figure 2); Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacturing, Repurpose, Recycling and Recover energy (Rood et al. 2017).

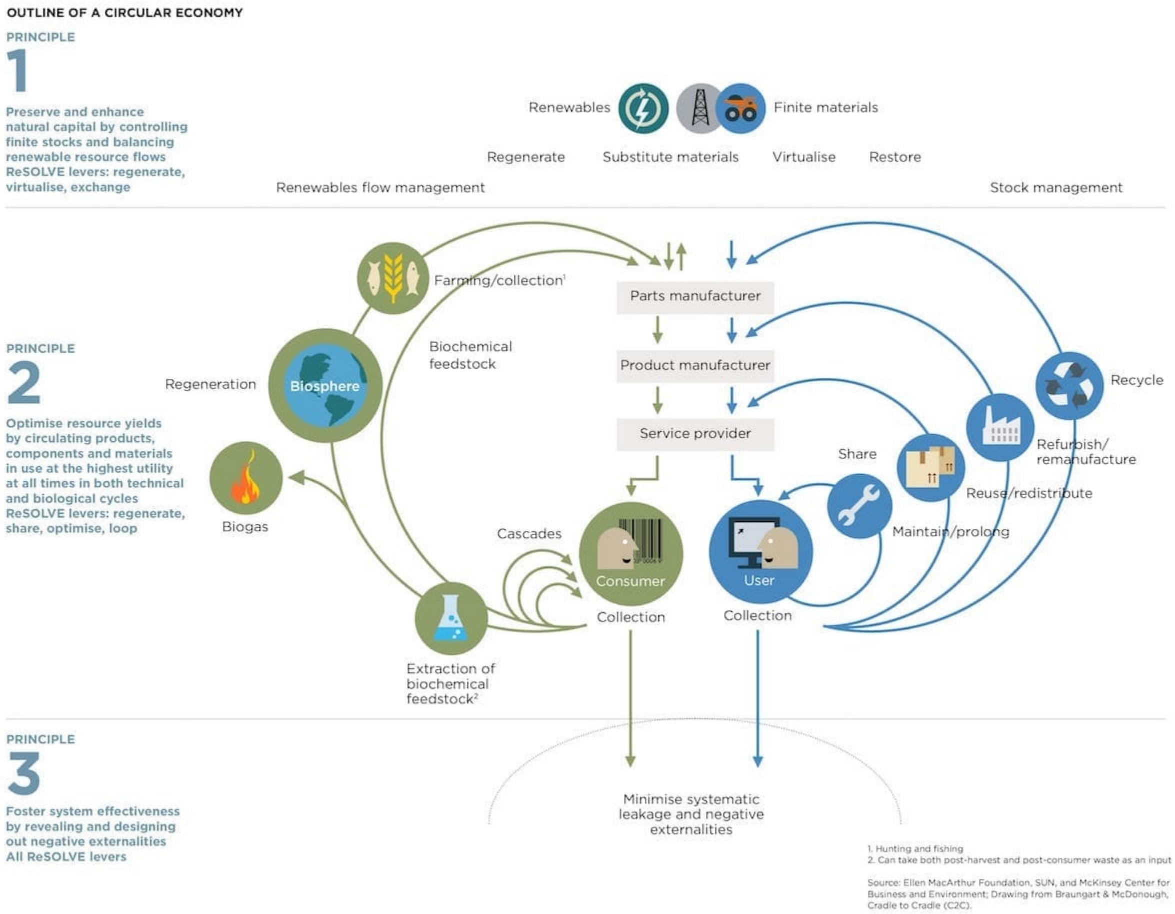


Figure 2. Butterfly diagram circular economy. (Ellen MacArthur foundations)

Circular economy in the Netherlands

The transition to a more sustainable and CE creates opportunities for the Netherlands. TNO estimated the potential decrease in greenhouse gasses of the CE and what it will contribute to the National climate goal. By the year 2030 around 7,7 Megaton CO_2-equivalent (20% of the national policy statement) and in 2050 13,3 Megaton CO_2-equivalent. One other additional advantage is, that the Netherlands would become less dependent of importing resources and not be dependent on geo-politics (Rood et al. 2017). Within the Netherlands are around 85.000 circular initiatives registered and an estimated 420.000 jobs are connected with these initiatives. The distribution of these initiatives in the Netherlands is uneven and in the large cities the initiatives are more represented (Rood et al. 2019).

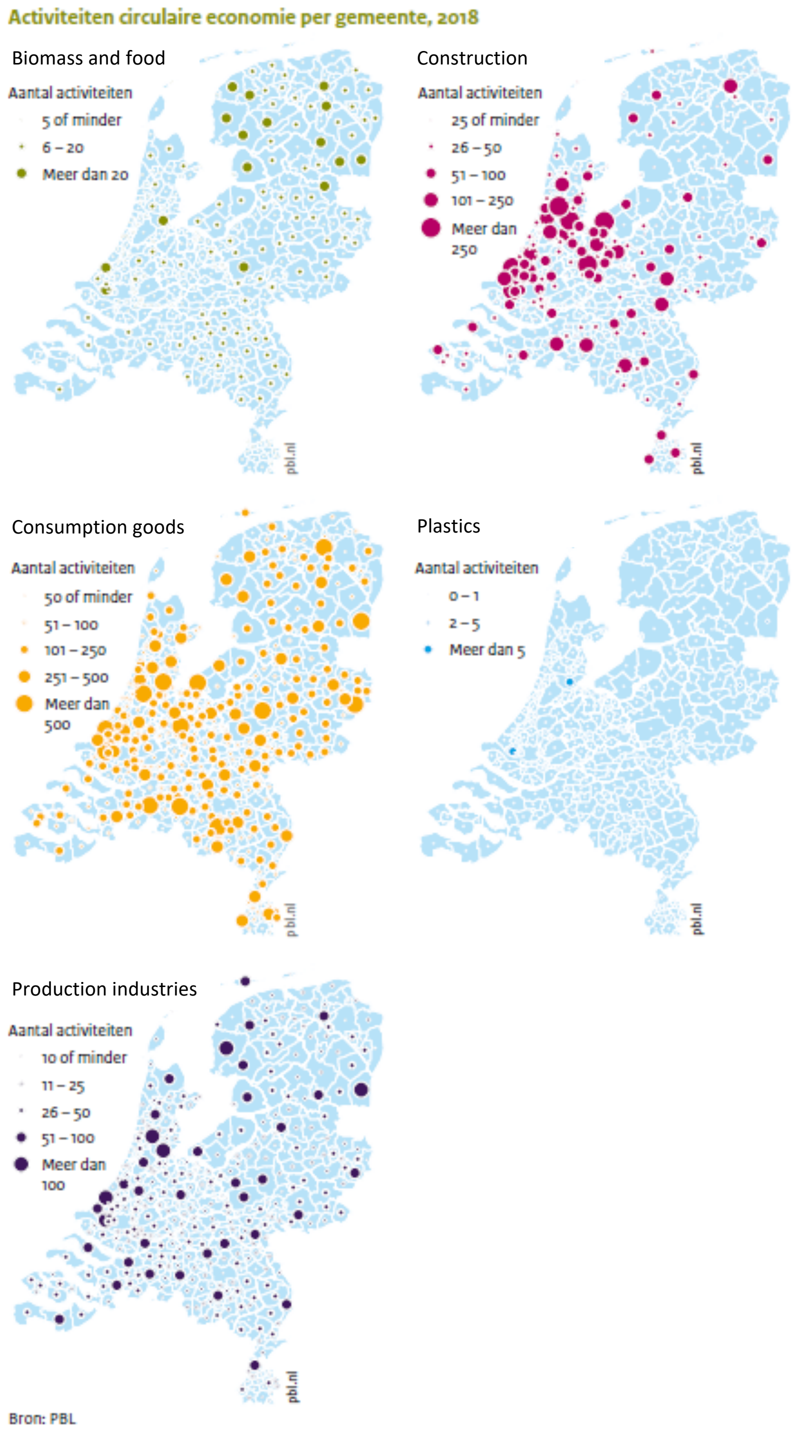


Figure 3. Circular activities in the Netherlands per category (PBL – Rood et al. 2019)

Looking at the distribution of circular initiatives per sector (figure 3), it becomes visible that most of the initiatives are in the large cities. However, the Biobased sector is more represented in the (North) East compared to the other sectors.

Circular economy in North Brabant
The CE in North Brabant is constantly in motion and the goal is to be fully circular by the year 2050. The province wants to anchor the circular thoughts in their organisation and uses the circular principles in their purchase strategy. The social challenge is the departure point, the shift from economic perspective to a more environmental perspective is on-going in North Brabant. The province sees the opportunities of implementing the CE in their well-known high-tech and design sectors, in combination with IoT, digitalisation and big data. (Province North Brabant. 2019)

2.2 4th industrial revolution and the circular economy

The 4th industrial revolution indicates that three revolutions took place before this revolution. The first revolution is characterised by mechanical powered production, the second was the introduction of mass production, and the third was the implementation of IT and automated production. The fourth revolution is characterised by the "cyber physical systems". "These systems are a consequence of the far-reaching integration of production, sustainability and customer satisfaction forming the basis of the intelligent network systems and processes (Bloem et al. 2014)."
The 4th industrial revolution is driven by data, these data can be used for different purposes; data collection, data analysis and data integration (Pagoropoulos et al. 2017). For every purpose a certain technology from the 4th industrial revolution is most suitable (figure 4), in the following sub paragraphs the purposes and the technologies are explained in relationship with the CE.

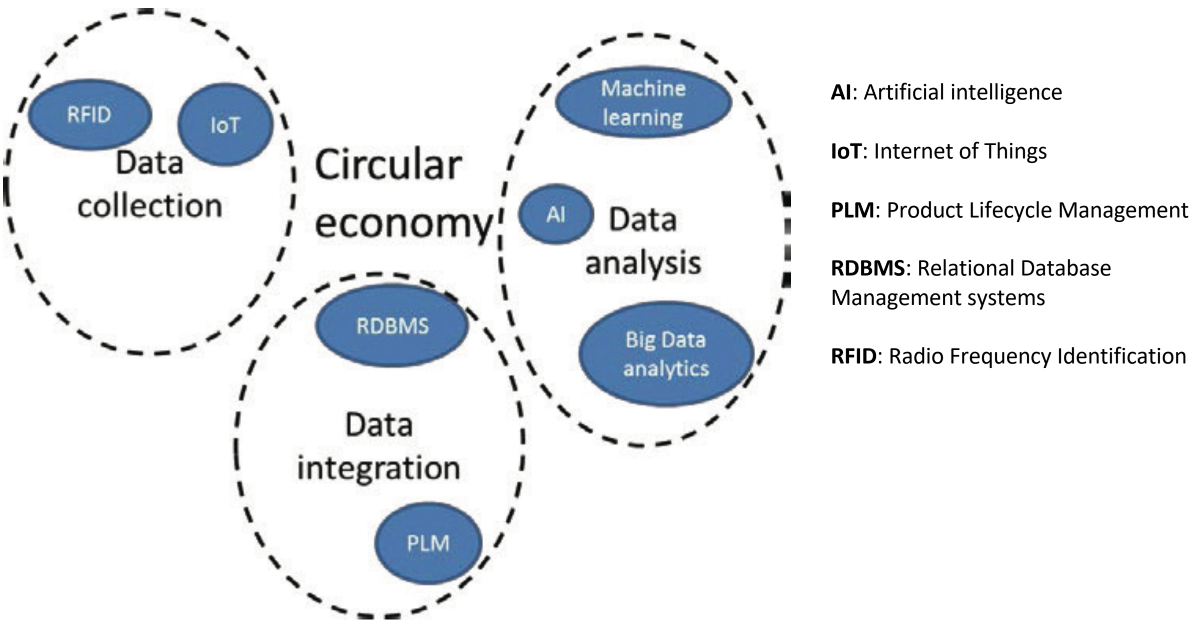


Figure 4. Grouping of digital technologies according to three architectural layers. (Pagoropoulos et al. 2017).

According to the World Economic Forum (2019), the technologies from the 4th industrial revolution are helpful for implementing the CE. In figure 5 an overview is illustrated in which phase of the loop the technologies can be of added value. Most of these technologies are explained in the following sub paragraphs. These technologies can also be helpful to overcome the faced challenges which occur during the transition from a linear to a circular business model (Rajput et al. 2019).

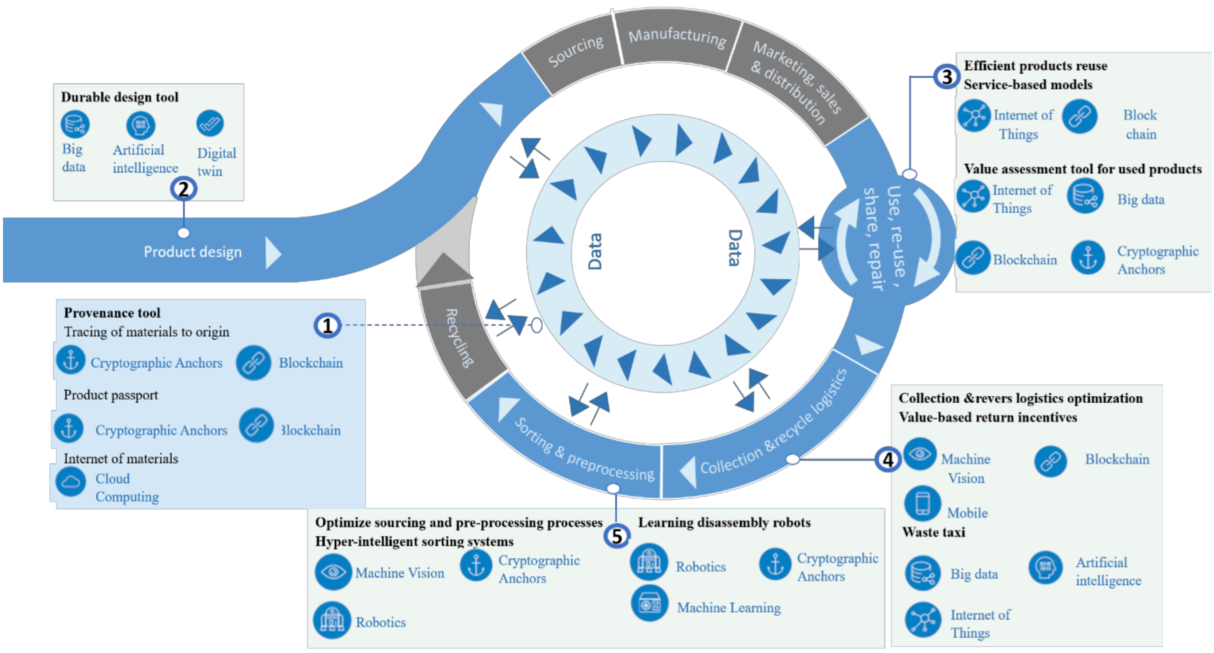


Figure 5. Visualization of the 4th industrial revolution technologies, based circularity enhancing solutions. (World Economic Forum. 2019)

Data collection technologies

Data can be collected by the Internet of Things (IoT). The IoT can roughly described as; devices which are connected with the internet (washing machines, cars, smartphones etc.). These devices are connected with the internet, they contain a lot of information which is useful in many ways, this useful information is so-called "data" (Pagoropoulos et al. 2017). The rapid increase in the number of devices connected to the internet is reshaping our economy and will create a lot of value. A new sort of data is being harvested, collected and shared as never before. This enables new ideas and insights how to innovate in a resource limited world. The closing gap between the technological world and the natural world will be beneficial for the implementation process of the CE in general. The future will prove if digital technologies are able to decouple resource consumption from economic development (Ellen MacArthur foundation. 2016).

In the context of CE, IoT can be a useful source of information. "IoT can collect information generated by sensors to connect stakeholders across the value chain (Pagoropoulos et al. 2017)". In this systematic change of perspective, IoT becomes the new virtualised infrastructure that manage the assets and movements in the value chain. The value created by IoT does not only have influence on the direct linked business, but the created value can be used in a broader context. For example, "San Francisco has installed solar powered sensors enabled waste bins that measure waste levels and compact items to reduce overflow (Ellen MacArthur foundation. 2016)". By using this system the operations costs decreased by 10%-80%, because of the efficiency (Ellen MacArthur foundation. 2016).

Digitalisation of our economy has the potential of changing our linear economy dramatically. Placing Radio Frequency Identification (RFID) on products during the life cycle will gather a lot of valuable information, which is beneficial for customers. Companies will use this information to improve their products and the lifecycle will be extended. RFID is a technology to mark your asset with a tag, these tags contain transponders that emit messages, readable by RFID readers (Weinstein. 2005). Depending on the type of tag (passive or active) the range of the signal is determined. The RFID technology will help to track the flow of a product and implantation of the R-strategy will simplified. RFID will also help executing of reverse logistics (Pagoropoulos et al. 2017). A famous example is pallets, which are equipped with the RFID tag by the production company and uses the business model, product as a service. Due to transport movements the pallets are distributed over a large area, the RFID technology enables to locate the pallets (RFID store. 2015).

Nowadays the linear economy is organized in this way; take-make–waste. The production company its interests are making as much profit as possible, by selling as many products as possible. The interest of a company will change if they use a different kind of business model; product as a service. Product as a service is one of the business models which are supported by CE and it means; the customer is leasing a product for a fixed price for a period and the ownership will stay with the company. Product as a service changes the ownership of the product, this is essential because the company's interests are shifting from selling as many as possible, to having the product last as long as possible. Data gathered by the RFID technology during the life cycle will become more and more important for extending the lifecycle of a product and for the implementation of the CE in general (Ellen MacArthur foundation. 2016).

The Ellen Macarthur conducted an overview (table 1) of the interactions of intelligent assets and the circular economy. They mention value drivers and examples of value creation options.

	INTELLIGENT ASSET VALUE DRIVERS		
CIRCULAR ECONOMY VALUE DRIVERS	Knowledge about the **location** of an asset	Knowledge of the **condition** of the asset	Knowledge about the **availability** of the asset
Extend the use cycle length	Broken parts can be identified -> lifecycle can be expended. The route can be planned precisely -> less wear on the vehicle.	Prediction can be made about the replacement of failing parts -> asset less chance on failure Changed use patterns -> wear can be minimized	Improvements of the design of a product Extensive usage information -> can optimize the product
Increasing **utilisation**	Extensive route planning Localisation of shared assets	Predictive maintenance -> avoiding downtime Input can precisely be managed in agriculture (e.g. fertilizers)	Next user of the asset has automated connection Overview of the available space, e.g. parking
Looping the asset through additional use cycles	Planning for the reversed logistics Location is known -> product is traceable on the secondary markets	Predictive manufacturing Valuation can be made and being compared with other assets Decision can be made for future loops	Product no longer in use ->improved reuse and recovery of an asset Local digital marketplace
Regeneration of natural capital	Distribution of biological nutrients can be tracked and automated Tacking natural capital	Land degradation can be identified in an early stage Condition of natural capital can be monitored	

Table 1. Interactions of circular economy and intelligent asset value drivers and example of value creation opportunities. (Ellen MacArthur foundation. 2019)

To clarify table 1, the mentioned value drivers of both the CE and the intelligent assets, they are explained in order to show that intelligent assets can be beneficial to the CE. Extending the lifecycle of a product, component or material, will reduce the demand and the added value during manufacturing, will be maintained. Extending the lifecycle of a product starts in the design phase, the circular design is based on durability easy to repair and easy to upgrade. Sharing is a good example to increase the use time. After the lifecycle of an asset it can be reused, remanufactured and/or recycled in the current cycle, however it can also be used in different cycles. In addition to this, it can be used in the same and different cycle(s), but the highest value of the product needs to be maintained (Ellen MacArthur foundation. 2019).

Data analysis technologies

“Big data is the information assets characterised by such a high volume, velocity and variety, that it requires a specific technology and analytical methods for its transformation into value (De Mauro et al. 2015)”. Big data analytics (BDA), gives insight, reduces uncertainties and has a predictive character, which makes decision-making easier. Based on data from the past, a pattern is recognised, this makes the authenticity of the predictions more acceptable (Gupta et al. 2018). In a circular context BDA can be helpful to develop automated processes and to asses pathways for secondary materials (Davis et al. 2017) or possibilities for industrial symbiosis (Song et al. 2017), developing open source data, services and tools for reuse (Franquesa et al. 2018), assessing innovative business models (Chiappetta Jabbour et al. 2017), managing and gathering data during the lifecycle (Li et al. 2015) or the implementation of smart industry practices (Kusiak. 2018).

Artificial intelligence (AI) is the general name for a collection of technologies, which deals with systems and models that simulate human functions such as; learning and reasoning. AI is based on data from e.g. text, audio, images and videos, and AI is used for e.g. optimisation, prediction and recognition. AI algorithms are developed by; data collection, data engineering, algorithm development/refinement, the desired outcome is solving a particular problem (Ellen MacArthur foundation. 2019). The gathered data is also used as input in machine learning. As assets become more artificially intelligent, they are going to communicate between each other and work together and this eliminates human intervention. With the increase of AI in machines, it can eventually function autonomously.

In this world with the immense increase in data and connectivity, AI can play a role in expending and complementing human capacities. For example; AI can recognize a connection between different parts of the network or data set which it functions in and generate a solution beyond human capacities (Ellen MacArthur foundation. 2019). In short, the gathered data by IoT, RFID and sensors can be analysed by AI, which spot the trends, optimises systems and asset management in the CE (Ramadoss et al. 2018). The Ellen MacArthur foundation has mentioned that AI can unlock three high potential circular opportunities These opportunities are mentioned and explained below:

1. *Design circular products, components, and materials*

The complexity which occurs during the design phase of a product is enormous. AI can support the designer with a continuous feedback loop where designers test the AI generated ideas. This could lead to better outcomes in a shorter timeframe.

During the composition phase of a new material, AI could assist by suggesting a substitution ingredient instead of the toxic/harmful variant which is used now. Or there may be a local material available (e.g. by-product from other nearby company, industrial symbiosis) which is a substitution material for a now used virgin material variant. (Ellen MacArthur foundation. 2019)

2. *Operate circular business models*

Circular business models are models which propose new propositions such as; competing with a fully circular model to a linear model, sharing economy and product as a service. Algorithms and dynamic pricing have proven the potential of these sharing and access models. Other sectors are ready for this kind of innovative AI driven circular business models. However, the implementation on a large scale is not there yet.

An additional phenomenon occurs with some of the circular business models, this is called reversed logistics. A model can choose to return the product after its lifecycle for reuse, remanufacturing or harvesting materials for remanufacturing, and recycling. The changes in demand, supply and the condition of the returned products makes a uniform model hard to make. AI can solve this problem and make the model more feasible. However, it can only function with large quantities of customer data. Under this condition an AI model can make sense out of it. AI can be directly applied in price setting, forecast demand and in creating platforms to trade secondary resources and products. (Ellen MacArthur foundation. 2019)

3. *Optimise infrastructure to ensure circular product and material flow*

The gathered data in this internet and ICT rich environment is growing exponentially each day and can be used for optimizing the ecosystem. Many devices in our ecosystem are monitoring and tracking the movement of a certain action. This data rich heterogeneous stream provides a lot of information about the inhabitants and their living environment. The data enables a real time analysis of the interconnections within an ecosystem, these interconnections can be used for planning, design and development. On the other hand, the data is a valuable raw resource for executing a more sustainable and circular approach within an ecosystem. (Sukhdev et al. 2017)
The gathered data can also be useful for both the biological cycle and the technical cycle. It is necessary to regain the highest value as possible out of the used products. For the biological cycle this means giving the nutrients back to the earth, and for the technical cycle to sort the used products in to homogenous "waste streams". AI can help with an effective way of sorting these waste streams into homogenous and pure streams. "In general, the better the material streams are pre-sorted and separated, the higher the recovery level, the more components can be identified for reuse and remanufacture, and the higher the quality of materials extracted during recycling (Ellen MacArthur foundation. 2019)". AI already shows its value in this process of creating value through the implementation of visual recognition techniques. (Ellen MacArthur foundation. 2019)

Data integrations technologies

Relational Data Base Management systems (RDBMS), are systems which organise the data in a way that heterogeneous streams of data can be integrated and presented in formally described tables (Pagoropoulos et al. 2017). RDBMS systems can support the goals of the CE by handling and integrating the collected data by IoT and RFID. According to Salminen et al. (2017), standardization of data in waste handling can reform the value network.
Product Lifecycle Management (PLM) is an information management system. PLM can support the CE, because the system can integrate data across multiple lifecycles and between different stakeholder within the value chain (Pagoropoulos et al. 2017). According to Lieder et al., PLM is also important on a company level as it enables product monitoring throughout multiple lifecycles.

2.3 Data driven ecosystem

Digitalisation enables monitoring and identifying challenges within (urban) areas. More effective decision making, and spatial planning can be arranged in regard to how to tackle these challenges and how to prevent them for happening in the future. According to the Ellen MacArthur foundation (2017) four technologies have been identified as enablers of the CE in (urban) areas. First, asset tagging can provide information about the condition and availability of products. This measure is helpful by extending the lifecycle and it will increase the utilisation. Second, geo-spatial information provides the location of an asset and the flow of an asset becomes traceable. Due to this information it is possible to map waste, efficient mobility routes, pollution etc. Strategic management and decision making can be adjusted based on the geo-spatial information. Third, big data management can be used for combining all different kind of data. The data gathered from human behaviour can be merged with the data from asset tagging and geo-spatial information. The most well-known example is predicting congesting during rush hour. Fourth, connectivity is a granted phenomenon in the western world and

it enables circular business models such as reserve logistics, sharing platforms and leasing. (Sukhdev et al. 2017)
IoT based smart cities and urban planning can have a major impact on the development of an area. It enables effective, intelligent decision power at the right time by using the big data gathered from the IoT. The IoT based datasets, such as surveillance, parking, traffic, weather and pollution can be used for urban planning decisions. These datasets can be helpful for both the inhabitants and the government to make intelligent and fast decisions. (Mazhar Rathore et al. 2016)
To create a data driven ecosystem it is necessary to merge the above-mentioned technologies together. The idea of a data driven ecosystem is derived from biological ecosystems, organism interreact between each other and with their environment. Also, thoughts from business, software and digital ecosystems are implemented in data driven ecosystems. In this case, data driven ecosystems consist out of three main components; network, platform and co-evolution (Oliveira et al. 2018).

2.4 Considerable ethics around the 4th industrial revolution

Besides all the mentioned opportunities it also a sensitive and ethical topic. The inhabitants of the Netherlands are associating AI with; robots, computers, intelligence and learning. They are expecting that AI will play a big part in the field of media, employment, economy, safety and healthcare. But they expect that AI will have no or less influence in the justice system. According to a survey done by Kantar Public (2018) the inhabitants allow the government to use AI in case of taking over heavy work, more efficient use of resources, bigger problem-solving ability or accelerating processes.
The main concerns of the inhabitants according to Kantar Public are; wrong decisions caused by incorrect data, correction of the faults made based on AI, not including people with special circumstances and a threat to our privacy.
Based on the report made by the Rathenau institute an overview is made which indicates the social and ethical questions, that occur due to digitalisation. Table 2 elaborates further on these social and ethical questions per theme.

Theme	***Question about***
Privacy	Protection of documents, privacy, mental privacy, surveillance, shifting of the goal
Autonomous	Freedom of speech, manipulation, paternalism
Safety	Information security, identity fraud, physical safety
Control over technology	Control and insights in algorithm, responsibility, unpredictable
Human dignity	Dehumanisation, deskilling, decrease in socialisation, technological unemployment
Justice	Discrimination, exclusion, equal treatment, stigmatisation
Power ratio	Unfair business climate, relationship civil society-government-company

Table 2. Social and ethical questions by digitalisation (Kool, L et al. 2017)

The insufficient knowledge about technologies and their moral role in society makes the decision part hard. New approaches are urgently needed, especially with those technologies which blur the lines between human and technological capabilities (Philbeck et al. 2018). Since the digitalisation has reached some privacy sensitive sectors, it becomes more and more important to monitor and control the algorithms that drives the digitalisation. Impacts of digitalisation cannot be underestimated, the ethical questions are related to important values of the international treaties and the Dutch constitution. Digitalisation will influence public values and it is an important challenge to govern ethical problems. (Kool et al. 2017)

3.0 Methodology

Introduction

For this explorative research qualitative methods are used. The main aim is to explore the relationship and potential between the three main components: the 4th industrial revolution, CE and the spatial component (ecosystem Mid Brabant). Qualitative research is the most suitable, because qualitative methods are used to reveal a potential (Hammarberg. 2016). Within this research the researcher wants to reveal the potential between the CE and 4th industrial revolution in the ecosystem Mid Brabant.

Methodology sub question 1 - Which economic clusters, hubs and other relevant activities are present in the ecosystem of Mid Brabant?

The first sub question is characterized by desk research. The desk research consists out of analysing relevant policy documents (e.g. policy agreement North Brabant), documents about the regional- and provincial economy (e.g. SMA – Hart van Brabant), advising documents about digitalisation, general advice documents (e.g. Brabant Advice organ) and internal documents (e.g. functions MBC). It is essential to gain knowledge about the economic priorities, hubs and relevant processes within Mid Brabant, in a data driven and circular perspective. This sub question allowed the researcher to get to know the region and linkages within Mid Brabant.

Methodology sub question 2 - Which data driven programmes from Midpoint Brabant, MOED and educational organisations can contribute and deliver synergy to Midpoint Brabant Circular?

Before researching this sub question, it was important to get knowledge about the context of the close involved organisations. The methodology was mainly based on interviews. The original method was to execute interviews with managers from the applications areas of Midpoint Brabant to gain the data and knowledge for this sub question. Due to Covid-19 less interviews were conducted as expected. However, several interviews were taken. The interviews are not part of the results, but are only used for the context. The interviews were unstructured with the following participants:

- *Tjerja Geerts (Midpoint – Business development smart services)*
- *Ralf Daggers (Midpoint – Programme director smart services)*
- *Herman Gels (Midpoint – Programme director CE)*
- *Nick van Soest (Brabant Environmental Federation – intern HAS)*
- *Rob Haenen (Floow2)*

The information concerning the closed involved organisations is derived from analysing the programme outlines and websites (desk research). Based on the context, websites and programme outlines the researcher got a clear view of the current activities in these organisations. These current activities are reviewed by searching relevant literature. This reviewing process can be best explained by an example: the smart services programme outline mentions that there is an important relationship between technological developments and social innovation. Based on this relationship relevant literature was searched. Based on this literature an overview is conducted of what already was present in the smart services programme, what was missing and what should be added to make the programme more complete. All application areas of Midpoint Brabant (except the smart leisure programme, because this research is mainly focussing on make, transport and process industries) are researched by the steps mentioned in the example. The other mentioned organisations (Floow2, JADS, MOED and MindLabs) in this sub question are being analysed only.

Methodology sub question 3 - How can be a data driven ecosystem created around Midpoint Brabant Circular?

Within the third sub question the possibilities are researched in regards to the relevant concepts and programmes mentioned in the theoretical framework, sub question 1 and sub question 2 can merge together. The aim is to include all the relevant concepts, programmes and adding the missing opportunities, in order to create a data driven ecosystem (figure 6), where the CE can flourish in.

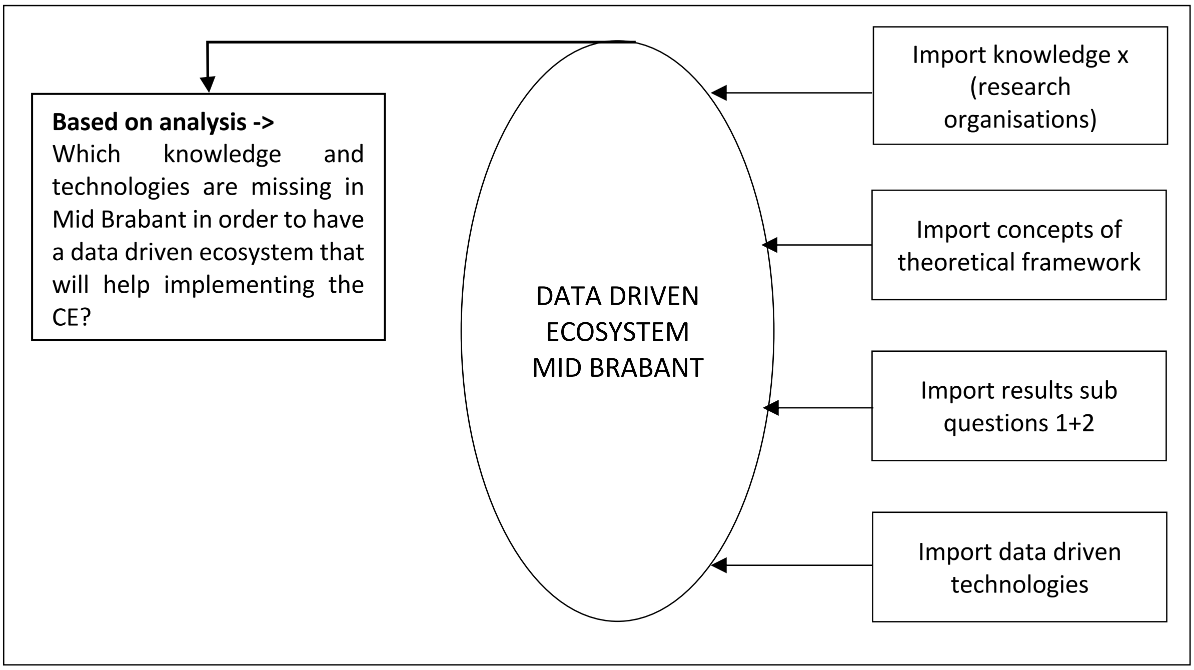


Figure 6. Systematic overview, how to create an inclusive ecosystem around MBC.

Before merging these concepts and programmes together, a basepoint is created to give an overview of the present relevant activities and the missing relevant activities. This base point is created based on the distinction of data driven technologies (collection, analysing and integration). After this basepoint the relevant activities are placed in the data driven ecosystem (in the network, in the platform or co-evolution).

4.0 Results

4.1 Current situation in the ecosystem Mid Brabant

Introduction

It is important to make a system analysis of the area in which the research takes place. Within this chapter the main economic activities, demographics, labour market, hubs, digitalisation status and other relevant activities are taken into account.

The region Mid Brabant consists out of the following municipalities; Dongen, Gilze en Rijen, Goirle, Heusden, Hilvarenbeek, Loon op Zand, Oisterwijk, Tilburg and Waalwijk. The interest of these municipalities together is represented by Hart van Brabant and Midpoint Brabant. Midpoint Brabant and Hart van Brabant conducted a strategic multiple year agenda (SMA) (2019-2023). This document is an important source of information for this sub question.

Demographics

Within the nine municipalities of Mid Brabant are almost 45.000 are businesses established and 50.000 students are studying on one of the five MBO, HBO or university. The region is building on an previously created fundament and this gives the region the opportunity to reinforce their position. According to Hart van Brabant, the population will slightly rise in the upcoming years to 450.000 people and will be distributed as described in figure 7 (SMA – Hart van Brabant).

Figure 7. Total in habitants 2018 and prediction for 2040. (SMA - Hart van Brabant. 2019)

According to the province of North Brabant (2017), the population of Mid Brabant will be around 430.000 by the year 2040. Two other trends are visible (appendix 3); a decreasing population in rural areas and an increase of population in urbanized areas. This migration to urbanized areas is nothing new, however it will increase the pressure on the infrastructure in urbanized areas significantly.

Another phenome is the ageing population, the upcoming years will the amount of 65+ people go from 470.000 to 730.000 in 2040 in the province North Brabant, an increase of 55% (Province North Brabant. 2017).

Knowledge axis Mid Brabant
The geographical location of Mid Brabant makes it possible to collaborate with the surrounding regions to research the data economy in North Brabant (figure 8). In the South-East is the Technical University of Eindhoven situated, which is focussed on the high-tech industry. In the North-East is the Jheronimus Academy of Data Science (JADS) situated, which is focussed on datafication. In the West is the Breda University of Applied Sciences situated, which is focussed on logistics. In Mid Brabant is the Tilburg University situated, which is focussed on an advanced society. Other knowledge institutes in Mid Brabant are Fontys, Avans, ROC Tilburg and Helicon. (SMA – Hart van Brabant)

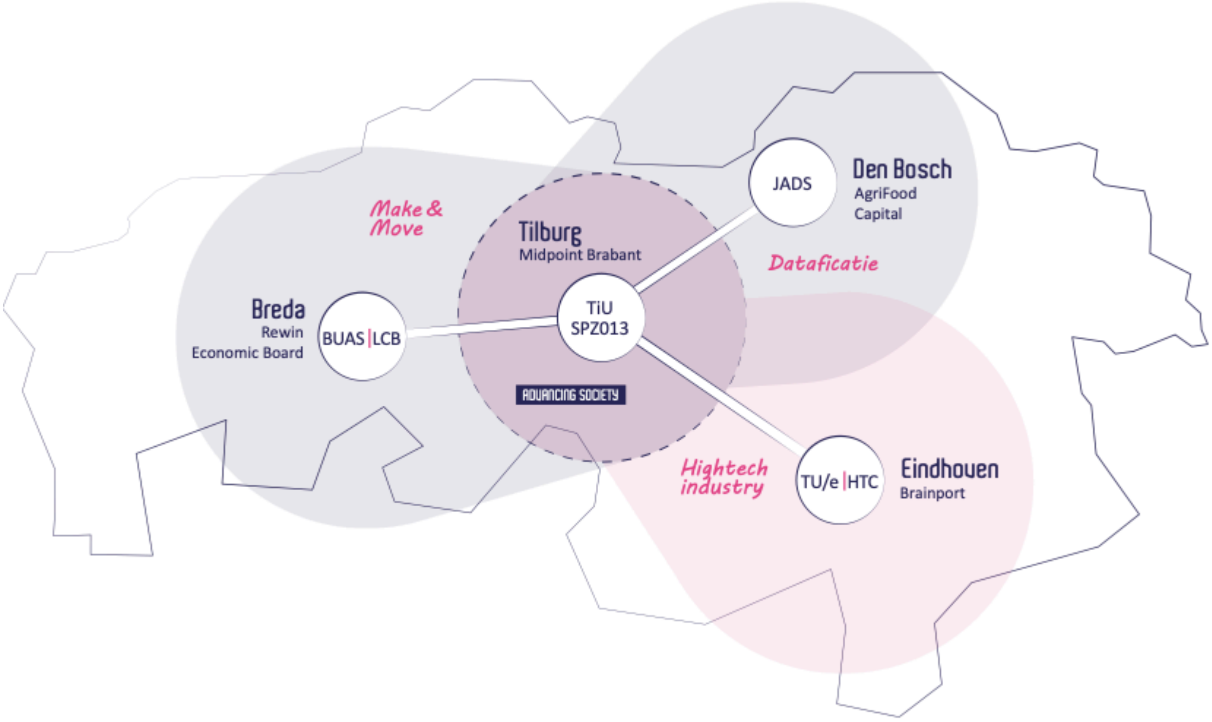


Figure 8. Knowledge axis Mid Brabant. (SMA - Hart van Brabant. 2019)

Labour market
The economy in Mid Brabant in 2017 represented, 2,4% of the total economy of The Netherlands (figure 9) (ING. 2019). According to the ING the largest sectors in 2019 were, business services (26,8%), trade (19%), construction (12,2%), financial services (7,6%), other services (7,1%), industry (5,8%) and IT-services (4,3%) (ING.2019).

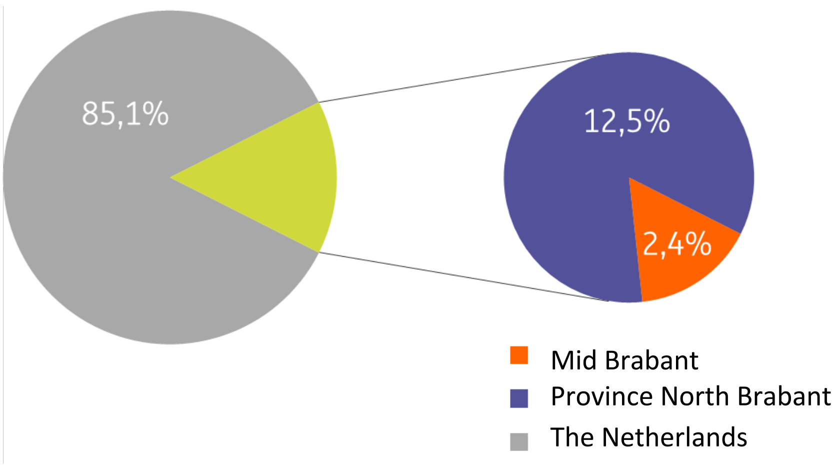


Figure 9. Market share Mid Brabant compared to North Brabant and the Netherlands, based on added value. (ING.2019).

The transition from a linear economy to a CE within these sectors is being researched. The main outcome is a list of companies, which (partly) use circular business models. The list illustrated in appendix 4 and consists out of almost 100 companies This is a fraction of the total established companies (40.537) in Mid Brabant (BrabantAtlas. 2019).
The labour market within the nine municipalities are developing by its own rate (figure 10). Within all municipalities the labour market is increasing and the largest increase is notified in Loon op Zand and the smallest increase is notified in Oisterwijk.

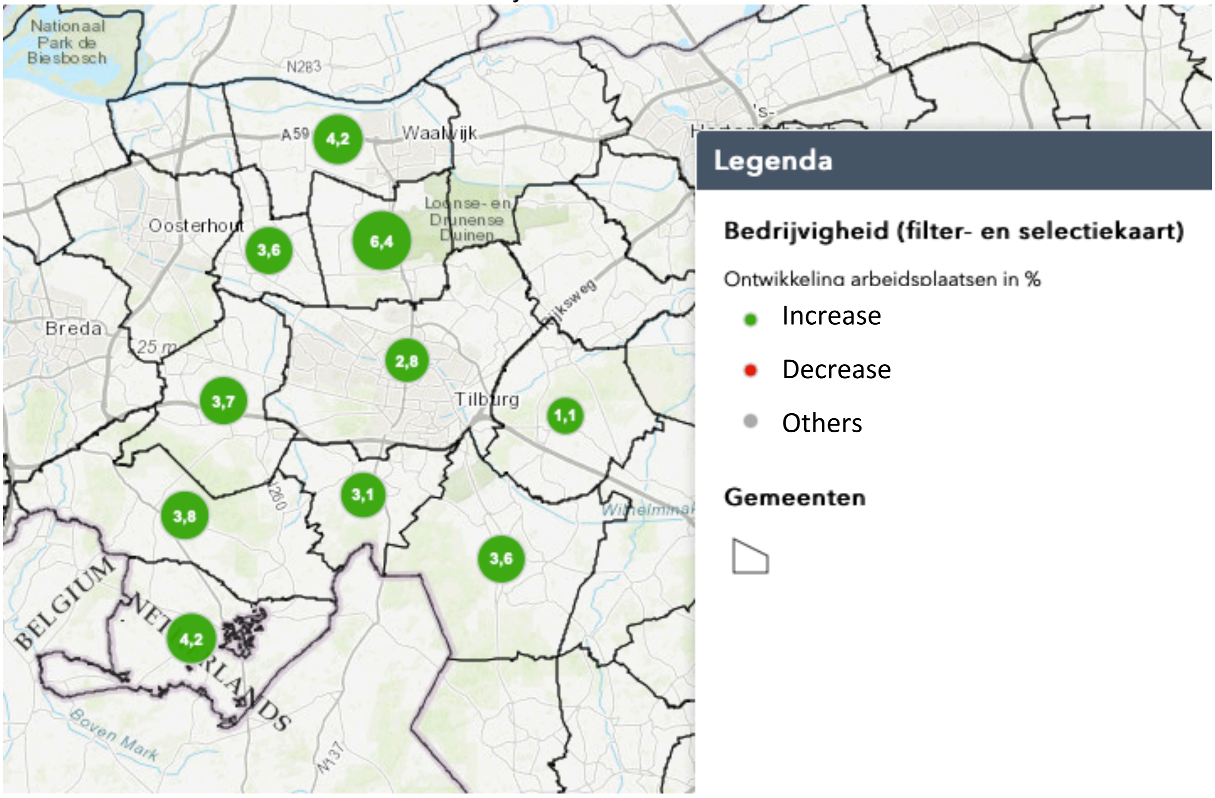


Figure 10. Development of labour per municipality in Mid Brabant. (BrabantAtlas. 2019).

It is important to have a well-balanced labour market in order to fulfil all the vacancies in the region. In the nearby future, routine jobs will cease to exist and due to the technological developments, the jobs will become more complex. To cope with this change in human capital competences, specific programmes needs to be formed in order to educate human capital future prove (McKinsey. 2016). In this area the industry sector and ICT sector are important and are being researched. In figure 11 is the distribution of jobs illustrated. The light blue dot on the top left of figure 11 represents the ICT sector, the jobs in the ICT sector have increased by 4,5% and ICT jobs in Mid Brabant are underrepresented compared to the Netherlands. According to the UWV (2019), it is hard to fulfil the vacancies of ICT-helpdesk employees, application and system caretakers, system developers, data scientists, programmers and developers with specific computer languages.

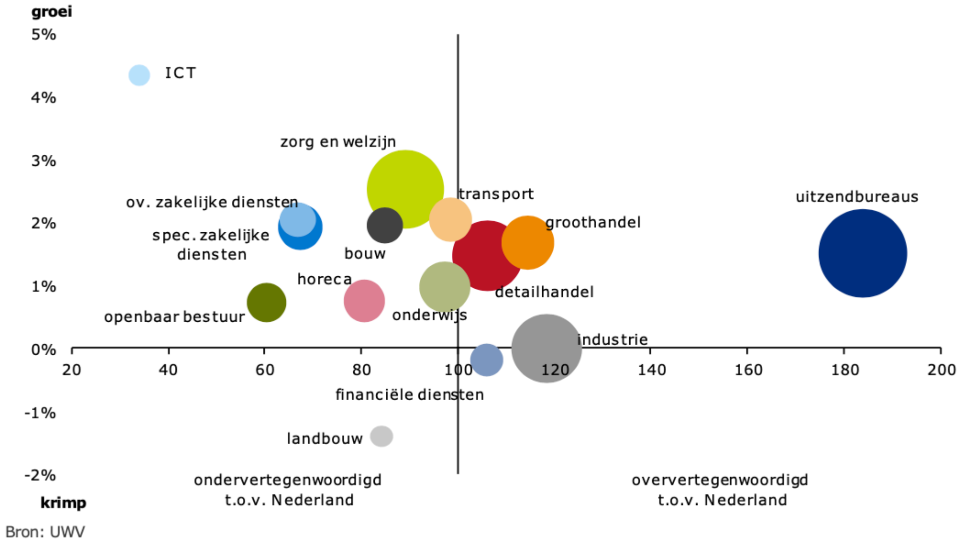


Figure 11. distribution of jobs per sector, share and development. Mid Brabant 2020. (UWV. 2019)
Explanation figure:
1. The larger the dot, the more jobs.
2. Expected relative growth or shrinkage in 2020 compared to 2019.
3. The relative interest of a sector for the employment in the local labour market in 2020. (share sector % local labour market/share sector% national labour market.

The industry sector is represented by the large grey dot in the middle of figure 11. The grey dot is large compared to the other dots, this makes it an important job engine for the region. The amount of jobs in the industry sector are staying stable and the sector is overrepresented compared to the Netherlands. According to the UWV (2019), it is hard to fulfil the vacancies of electricians, process operators, quality assurance, technicians, assembly employees and welders. The tension on both the ICT and industry labour market will not help to speed up digitalisation in Mid Brabant, it will also not be beneficial for the business climate in Mid Brabant.

Political situation North Brabant
On the 7th of May 2020, the new policy agreement of the province North Brabant is published. The coalition which formed this agreement consists out of VVD, FvD, CDA and Local Brabant (Province North Brabant. 2020). There has been a lot of controversy about this new policy agreement. However, they managed to make an agreement and the most important topics for this research are summed up underneath:

1. Working on a CE, by managing the available resources in a sustainable way.
2. The innovation power and the circular society of the province is placed in the economical portfolio.
3. To prepare the economy for "tomorrow", by increasing the digitalisation status and enabling key technologies.
4. Implementing data and digital technologies in their own organisations, to increase the efficiency.
(Province North Brabant. 2020)

Economic priorities
2019 was a turbulent year with the continuous drought, the nitrogen crisis and the farmers protest actions. Looking back at the past year shows that our current systems are not functioning anymore. Fundamental changes have to be accomplished in the upcoming years such as, renewable energy, sustainable economy and a healthy living environment (BrabantAdvies. 2020). On province scale the main goal is to be one of the top five most innovative regions in Europe. This entails six main economic clusters; high tech systems and materials, life sciences and health, food, logistics, maintenance and the Biobased economy. (Province North Brabant. 2020)

According to the SMA of Hart van Brabant (2019) the economic priorities of Mid Brabant are based on three principals. First, working on a smart society with social and ecological added value. Second, working on smart economy with a high economic efficiency. Third, the main value drivers are; knowledge, skill and character for sustainable development of our smart economy and smart society.

Status and potential data economy in North Brabant

The Brabant development agency conducted a market survey to research the potential of the data driven economy. As described in table 3, the estimated amount of added value that can be created by the data economy in North Brabant is 746 million. The percentage of market share for North Brabant compared to the Netherlands is roughly 13%. This percentage is a significant share of the whole market and can predict opportunities.

		Data economy (x million)	***Data market (x million)***	***Data employees (x thousand)***	***Data users (x thousand)***	***Data companies***
Brabant	***2016***	€2.102	€451	35	3	744
	2020	€3.526	€746	63	4	877
Netherlands	***2016***	€15.800	€3.400	262	25	5.600
	2020	€26.500	€5.600	477	29	6.600
European	***2016***	€300.000	€60.000	6.161	661	254.900
Union	***2020***	€430.300	€80.000	7.812	727	310.250

Table 3. Data economy in numbers on multiple levels. (Province North Brabant. 2017)

Within the market analysis, opportunities are mentioned for the companies in Brabant. They conducted a survey under different companies in the province and per sector (table 4). There is a certain linkage between these sectors and opportunities to cross over. This makes collaboration and data sharing important subjects in order to achieve the full potential. (Province North Brabant. 2017)

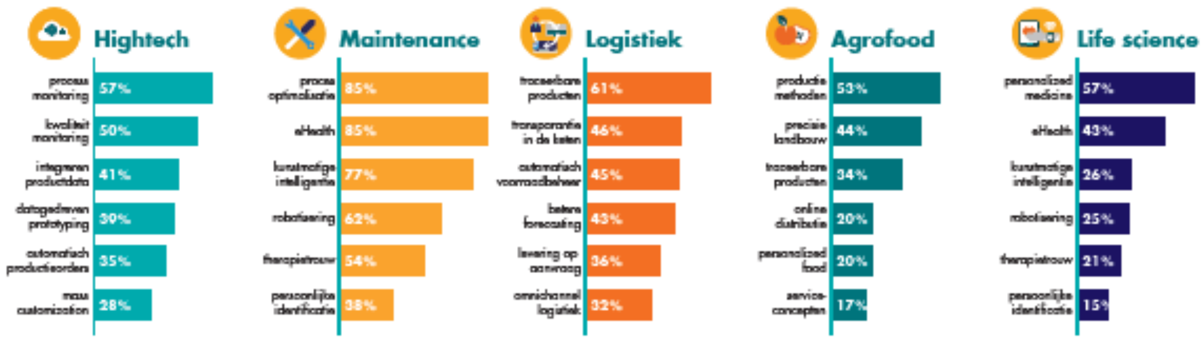


Table 4. Prioritising of changes per sector. (Province North Brabant. 2017)

Despite the great potential sketched by the province, the implementation of the data economy is not there yet. The majority (93%) of the companies in Brabant foresees obstacles, the major obstacle is being the insufficient knowledge about the topic. Other obstacles include to less expertise in data, resistance against implementation of data in the company itself and insufficient quality of data (Province North Brabant. 2017).

The province conducted an executing programme for the so-called high-tech sector. Within this programme four main sectors are indicated; smarts solutions, smart industry, smart cross-overs and smart data. These four sectors together will strengthen and create an ecosystem, which will create synergy. This interdisciplinary approach will function as an accelerant, will provide knowledge and will lower the threshold for companies that are not that familiar with the data driven economy (Province North Brabant. 2017).

Hubs

In Brabant a lot of specialized centres and knowledge centres are established. These centres are called hubs. MBC also wants to be a hub specialized in the CE. Another ambition of MBC is to be a hotspot (see background information MBC) for the region Mid Brabant and eventually on a national and European scale. In figure 12 are the hubs in the province North Brabant illustrated, with in the centre a large blue dot which represents MBC. The CE is interconnected with every hub, but a lot of separate hubs for the topic CE is not practical. That's why MBC wants to be the connector on the topic CE which, represents the hotspot function (internal documents MOED).

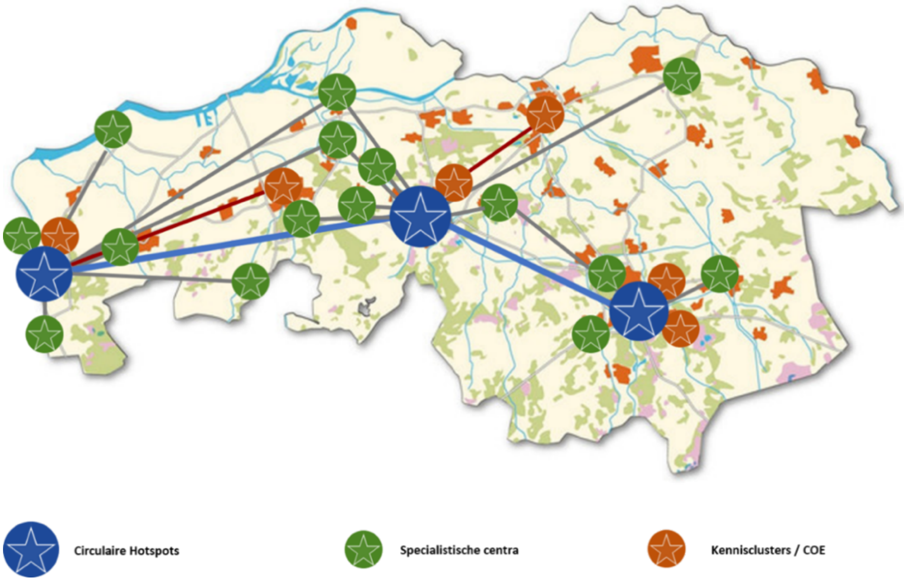


Figure 12. Overview hubs Mid Brabant. (internal documents MOED)

Zooming in on the scale of Mid Brabant (figure 13) a lot of different hubs become visible. The most important ones on data and circular aspects are elaborated in the next paragraphs such as JADS, Gate2 and MindLabs.

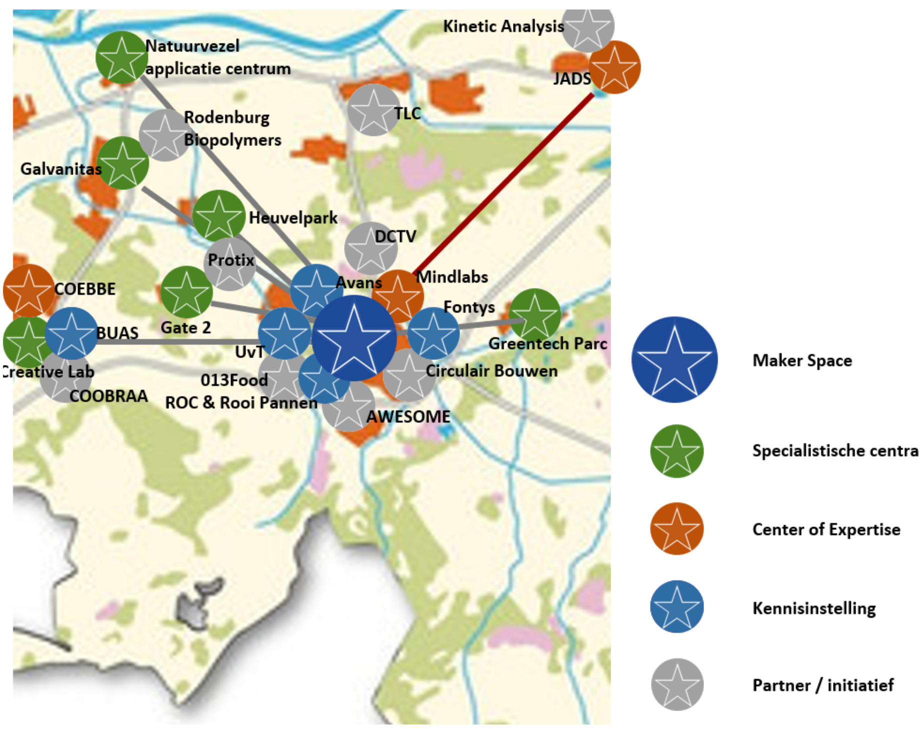


Figure 13. Overview hubs Mid Brabant. (internal documents MOED)

4.2 Data driven programmes of the closed involved organisations

Introduction

Within this chapter an analysis is produced to make an inventory about which data driven programmes are already present within the closed involved companies. One of the close involved companies is Midpoint Brabant as they have four application areas; smart services, smart industries, smart logistics and smart leisure. Another close involved company is MOED. They have the (data driven) programmes S4G and BioVoice. Also, educational/knowledge organisations related to data are being analysed such as MindLabs, Floow2 and JADS. The smart leisure programme of Midpoint Brabant is not included in this research, because it does not fit in the scope as explained in the methodology. This research is mainly focussing on the manufacturing, processing and transport industries.

Midpoint Brabant - Smart services

After analysing the programme outline it became clear that the smart services programme is more than an individual programme. The smart services programme is meant to be the programme which provides tools for the other smart programmes of Midpoint Brabant. An example of a tool could be a data lake (appendix 5), which could be helpful in many ways for all programmes of Midpoint Brabant. Mostly, data driven technologies are applied in order to gain economic growth. However, data driven technologies can be applied to improve society and to tackle urgent social tasks. According to the smart services programme outline, technological developments and social innovation have a close relationship. Social innovation can be fastened by using the collected data from various sources. Social innovation is "a novel situation to a social problem that is more efficient, effective, sustainable, or just than existing solutions and for which the value created accrues primarily to society as a whole rather than private individuals (Phills et al. 2008)". Possibilities for data driven social innovation are significant and can be beneficial for MBC. Various social tasks and problems exist in society and need to be solved with the existing means, methods and data. The means from the 4th industrial revolution are available, but not in open sources and not in sufficient quantity. Today's society generates an enormous amount of data, but much of this data is unused for social policy and social action (Pappas et al. 2017). The smart services programme should link the available data with social tasks and make the data open for researchers, businesses, society and students. According to Manyika et al. (2013) (social) innovation is directly linked to data availability and open data will lead to open innovation and the creation of smart regions.

Social innovation thrives under an inclusive ecosystem, where the actors within the ecosystem have multiple roles, as they may create or analyse data, using the outcomes of big data, create and influence relevant policies at the same time. Another condition is that the social innovation process should be in line with practices, guidelines and policies (Pappas et al. 2017).

Since data is becoming more available at lower costs, it can be used as a tool to identify the needs of society and offer services that are beneficial for society (Zicari. 2014). "A disciplined approach of social innovation through big data is needed in order to help, empower and support entrepreneurs and policy makers institutionalize mechanisms that increase the likelihood of initiating and implementing successful social innovation (Pappas et al. 2017)".

Midpoint Brabant - Smart industries

The smart industries programme is already characterised by data driven processes from the 4th industrial revolution. The programme is situated at the Gate2 campus (Gilze en Rijen), at the campus are multiple smart machines and data driven technologies showcased. The three main domains of the smart industries programme are data and communication technologies, simulation technologies and data driven manufacturing technologies (smart industries programme outline).

Within the 4th industrial revolution physical production technologies are merging together with data driven processes. The embedded systems, sensors, mobile devices and production technologies communicate with each other via the internet. This communication enables real time changes in the production line and more possibilities to produce smaller badges (Blunck et al. 2017). The data driven manufacturing technologies like, 3D printing, composites and material analysing are available on the Gate2 campus (smart industries programme outline). These technologies will help to establish the factory of the future and new circular business models. The gathered data of the manufacturing technologies could be an important source of information to help the entrepreneur with circular design questions. In addition to the economic benefits of a data driven production process, environmental and social benefits occur.

The potential of the 4th industrial technologies will help to establish the CE. First, these technologies are helpful to increase the resource efficiency, where every step in the production process becomes traceable and alternations can be applied right away. Even if sensors are placed within/on the final product, the product becomes traceable throughout the whole lifecycle. This procedure is called asset tagging. It will reduce waste and will increase the amount of resource within the technical cycle (Blunck et al. 2017). Second, the technologies improve utilization of assets. The production machines of most companies will last up to 20 years or more. This lifecycle can be increased by retrofitting them with sensors and smart tools. The old machine is upgraded to an intelligent asset, which can be functioning in the CE (Stock et al. 2016). Third, human capital is the driving force behind the 4th industrial technologies, but the need for certain skills is shifting to different competences. Routine jobs will cease to exist and due to the technological developments, the jobs will become more complex. To cope with this change in human capital competences, specific programmes needs to be formed in order to educate human capital future prove (McKinsey. 2016). The smart industries programme is already providing a programme for human capital, named skills lab (smart industries programme outline). Skills lab is a programme that will help to solve the tension on the labour market, mentioned in the first sub question. In collaboration with educational organisations and businesses in the region, new educational tracks will be developed with better connection with the labour market. Fourth, the management of inventories will be simplified by the technologies of the 4th industrial revolution. The gathered real time data about stock levels, will reduce waiting times, inventory costs and storage space (Song et al. 2016). Fifth, the quality of products will increase. Real time changes in the production processes will correct errors mentioned by the smart systems right away. Eventually less waste and less resources will be needed as well as the higher the quality of a product the longer its lifecycle will be (Blunck et al. 2017). Sixth, matching demand and supply. Data driven processes will provide a better forecast about the demand, which will decrease over production.

Another interesting programme managed by the smart industries programme, is the Dutch Digital Alliance (DDA). Within DDA there are eight digital orientated scale ups which are conducting a feasibility study for a collaboration in Tilburg for digital services, systems, processes and business solutions (smart industries programme outline). This collaboration can help to scale up the digital sector in Mid Brabant and will be a catalyst for digital related human capital in the region.

Midpoint Brabant - Smart logistics

The programme smart logistics is divided in to three tracks; innovation, CE and human capital (smart logistics programme outline). Smart logistics is an important link in circular business models. For example, reverse logistics as a major component of how the CE functions. Returning the products back after their lifecycle in order to maintain the highest level of the R-strategy as mentioned in the theoretical framework (Ripanti et al. 2016). How to retrieve the used products from billions of homes get them back in the material pool so they can be used again, shortly said bring the CE theory in practice. “Just some of the many needs of reverse logistics include asset tracking, materials recovery, dismantling, and toxic waste handling. Complexity of details necessitate that the design of reverse logistics and management of the circular economy will be some of the most highly refined systems thinking that modern society will ever create (Esposito et al. 2017).”

The first valuable programme is the Data sciences for Logistic Innovation (DALI) project. The aim of the project is to process, analyse and connect the collected data. This will lead to new insights, patterns and mutual connections (smart logistics programme outline). The project is a very useful source of information for circular business models. The collected data from the project is showing the used ways

and patterns of the logistics nowadays. By analysing the data, interventions can be suggested to alternate the current logistics and make it more sustainable.
The second programme is Pitch Logistics. Start-ups can pitch their innovative solution for a logistic problem. Moreover, challenges are subscribed from logistic entrepreneurs, these challenges need to be solved by the market (smart logistics programme outline). This actively searching for solutions is a great initiative and can also be applied with circular problems. Nowadays, there already is one similar project like pitch logistics, but in a circular context. The project is called BioVoice, BioVoice is a project executed in collaboration with Zeeland, West- and Mid Brabant, more information about this project is described in the sub paragraph MOED.
The last programme is the Logistic Academy, the linking pin between the logistic sector and the educational organisations. Improved connection with the sector will lead to more efficient educational tracks and an increase in human capital (smart logistics programme outline). As mentioned in the first part of this paragraph, rearranging the logistics sector to facilitate the CE is one of the most challenging system changes human will create.

MOED
The circular projects executed by MOED, BioVoice and Symbiosis 4 Growth (S4G) are frontrunners and the collected data is the foundation to build upon. S4G is based on the thoughts of industrial symbiosis. Industrial symbiosis is targeting the hidden waste streams within the industrial network that can be improve usage by cooperation (Homrich et al. 2018). Within S4G companies are brought together and share their haves and wants. The haves represents the resources they have in abundancy such as waste streams, over production, energy, heat etc. The wants are representing the needed resources. Based on the wants and the haves, matches can be created. The collected data is imported in a database (Synergie), so the data can be used and not get lost (internal documents MOED). The data such as quantity, location and matches are valuable to create inclusive ecosystem which is explained in the results of sub question 3.
BioVoice is a project where large companies (Dow chemicals, Cargill, Lamb Weston etc.) can challenge the market for an internal circular problem. The smaller companies, claiming to have the circular solution are becoming visible for the project team. These companies can be valuable if similar problems need to be tackled in another context as the contact is already there, and more impact can be created if they solve more similar cases (internal documents MOED).

MindLabs
MindLabs is collaboration between Fontys, ROC Tilburg, De Persgroep, Tilburg, North Brabant and Tilburg University that operates in the domain of interactive technologies and behaviour. It investigates human minds, artificial minds and pushes an innovative mindset (MindLabs. 2020)". The research between human behaviour and technological developments, like the 4^{th} industrial revolution is vital. If technologies from the 4^{th} industrial revolution are helpful by implementing the CE, the behaviour of people is important as they are the ones who have to implement the technologies in their lives and/or businesses. The research done by MindLabs can help to discover the thresholds for going circular and the thresholds for implementing the technologies from the 4^{th} industrial revolution, as mentioned in paragraph 2.4.

JADS
JADS is an educational organisation which provides data science programmes at undergraduate, graduate and post-graduate level. The JADS is situated at three different places, on the campus of Technical university Eindhoven (engineering), on the campus of Tilburg university (society) and on the Mariënburg Campus in Den Bosch (entrepreneurship). This data knowledge infrastructure within the province of North Brabant can make the province fit for the future. The mission of JADS is "to understand and advance the value of data in complex societal and business challenges" and the vision of JADs is "JADS serves an ecosystem in the province North Brabant, focussing on value creation for business and society based on data insights with a foundation in education and research" (JADS. 2020).

Floow2

Floow2 develops business to business sharing platforms. Floow2 makes it possible to start with the circular business model which is asset sharing. This type of business model enables collaboration between companies, closing the loops in value chains and industrial symbiosis. Floow2 already proved their competences in shared platforms for the construction sector, the health care sector, business park sharing and in the pharmaceutical sector (Floow2. 2020). After spoken to the co-founder of Floow2 (Rob Haenen), it became clear that Floow2 are researching the possibilities of RFID and IoT in their platform.

4.3 Data driven ecosystem

Introduction

The results of the first and second sub questions show the relevant data driven activities in the ecosystem of Mid Brabant. This sub question is being researches how all these relevant data driven activities merge together and form a data driven ecosystem. As mentioned in the objective, a data driven ecosystem can be best described as "Data ecosystems are composed of complex networks of organisations and individuals that exchange and use data as main resource. Such ecosystems provide an environment for creating, managing and sustaining data sharing initiatives such as smart cities, open data and scientific data communities (Oliveira et al. 2018)". The challenge in this sub question is to position the present activities in the ecosystem and add new data driven technologies in order to make it a well-functioning data driven ecosystem, which facilitates the CE in Mid Brabant. One important tool proposed by MBC, is the data lake (internal documents MOED & appendix). The data lake should be used as the storage space for the gathered circular data in Mid Brabant.

What is present and what is missing?

Based on the distinction in data driven technologies made in the theoretical framework, an overview is produced (figure 14). Within this overview the blue dots represent the current relevant activities and the red dots the missing activities to create a data driven ecosystem.

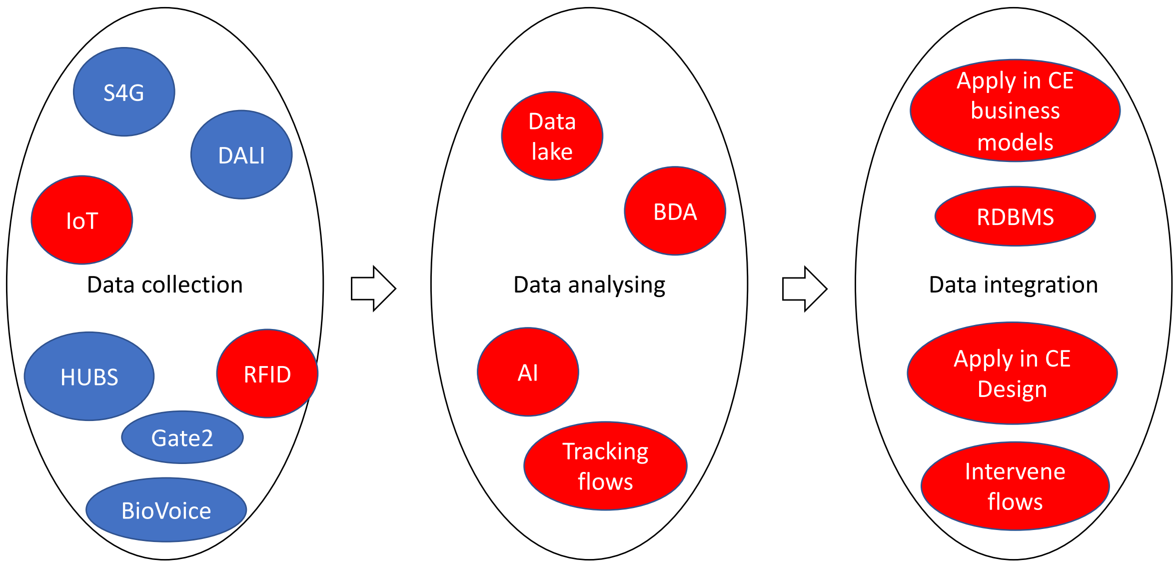


Figure 14. Overview of what is present and what is not present, divided into three categories.

As shown in figure 14 the current activities such as S4G, DALI, Gate2, BioVoice and Hubs in the region can be used for data collection. Moreover, IoT and RFID can also be used for data collection. As mentioned in the theoretical framework, by tagging the asset with one of those two technologies, the flow of a product becomes traceable. "IoT can collect information generated by sensors to connect stakeholders across the value chain (Pagoropoulos et al. 2017)". The RFID technology will help to track the flow of a product and implementation of the R-strategy will be simplified. RFID will also help executing of reverse logistics (Pagoropoulos et al. 2017).

The second circle in figure 14 is represents the data analysing technologies such as, AI, BDA and tracking the flow. The data lake is included in this circle because it will be the storage point for all the gathered data and the analysis will take place based on the data in the data lake. By using data from the past, a pattern can be recognised which makes the authenticity of the predictions more acceptable (Gupta et al. 2018). In a circular context, BDA can be helpful to develop automated processes and to asses pathways for secondary materials (Davis et al. 2017) or possibilities for industrial symbiosis (Song et al. 2017), developing open source data, services and tools for reuse (Franquesa et al. 2018),

assessing innovative business models (Chiappetta Jabbour et al. 2017), managing and gathering data during the lifecycle (Li et al. 2015) or implementating smart industry practices (Kusiak. 2018).
AI can play a role in expanding and complementing human capacities. For example, AI can recognize a connection between different parts of the network or data set which it functions in and generate a solution beyond human capacities (Ellen MacArthur foundation. 2019). In short, the gathered data by IoT, RFID and sensors can be analysed by AI, which spot the trends, optimize systems and asset management in the CE (Ramadoss et al. 2018).
The last circle in figure 14 represents the data integration technologies such as, RDBMS and PLM. RDBMS are systems which organising the data in a way that heterogeneous streams of data can be integrated and presented in formally described tables (Pagoropoulos et al. 2017). RDBMS systems can support the goals of the CE and can handle and integrate the collected data by IoT and RFID.
PLM is an information management system. PLM can support the CE, because the system can integrate data across multiple lifecycles and between different stakeholder within the value chain (Pagoropoulos et al. 2017). According to Lieder et al., PLM is also important on a company level as it enables product monitoring throughout multiple lifecycles.

Design
A data driven ecosystem consist out of three main components: the network, the platform and co-evolution. In a data driven ecosystem the network consists out of a loose network of actors. All these actors must produce value for the ecosystem and all actors can extract data from the ecosystem (Oliveira et al. 2018). In figure 15 is the network illustrated.

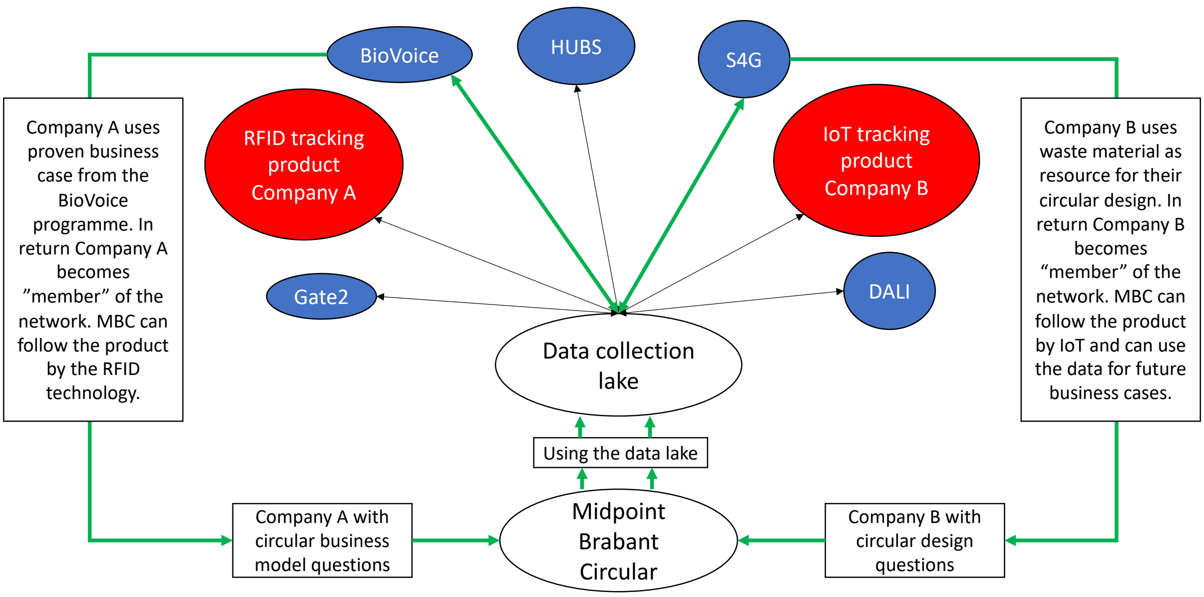


Figure 15. The network within the data driven ecosystem.

Within figure 15 two examples are explained; the examples correspond with the examples used in the appendix; harvesting data for the data lake. Company A has questions about a circular business model and decides to ask for MBCs help. MBC uses the data lake as a tool to serve Company A and the tool is suggesting a circular business model from the BioVoice programme. Company A agrees with this business model and in return Company A allows the network to follow their product(s) by the RFID technology. Company A contributes to as well as profits from the network.
In the second example, Company B has questions about the circular design of their product(s). Currently, Company B is using a toxic resource in their design and wants to replace this by a non-toxic resource. MBC uses the data lake and finds a non-toxic waste resource, which is a by-product in another industrial system. The non-toxic resource has almost the same material characteristics as the toxic resource. Company B uses the non-toxic resource in their design and in return Company B

becomes member of the network. Company B allows the network to follow their products which is valuable input for the data lake.
Another component of the data driven ecosystem is the platform, in this case MBC. The platform provides the actors of the data driven ecosystem with tools, services and technologies that can be used to generate benefits. The platform makes it possible to contribute as an actor to the data driven ecosystem (Oliveira et al. 2018). In this case the platform will provide tools, services and technologies for circular business models, circular design questions, (waste) material flow, product flow, (reverse) logistic patterns and topic specific information from the hubs.
The platform could visualize the ecosystem Mid Brabant. Figure 16 functions as an impression of how the platform could look like. Floow2 (results 2) made this platform. Within this platform it is not possible to track the flows real time. By using RFID and IoT the flows can be tracked and monitored in real time, Floow2 is researching this at the moment.

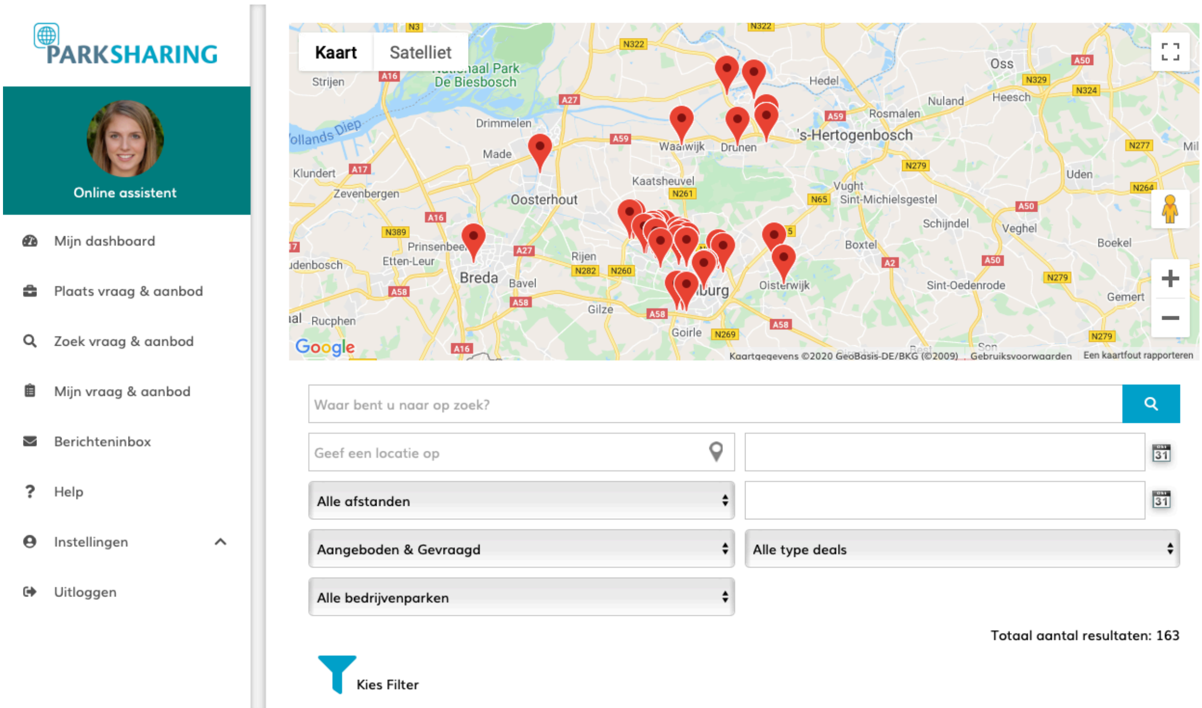


Figure 16. Screenshot Parksharing platform. (Floow2. 2020)

The last component of the data driven ecosystem is co-evolution. Being part of the data driven ecosystem demands connection between the actors. As mentioned in the sub paragraph Midpoint smart services, the actors within the ecosystem have multiple roles, as they may create or analyse data, using the outcomes of big data, creating and influencing relevant policies at the same time (Pappas et al. 2017). Collaboration between sectors and the actors in the network is necessary to achieve the full potential of the data economy in North Brabant (results 1). In this data driven ecosystem quadruple helix organisations collaborate together in order to achieve the full potential of the data economy in Mid Brabant.

5.0 Discussion

Introduction
In this chapter the research is discussed and reviewed. First, the value for MBC will be discussed. Second, the validity of the results and the limitations in literature are mentioned. Last, the feasibility of the data driven ecosystem is discussed.

Value for MBC
The aim of this research was to explore the possibilities concerning whether the technologies from the 4th industrial revolution can be applied to contribute to the CE in Mid Brabant. Many worthful technologies are identified and examples are given in which context these technologies can be used. There are many follow-up research possibilities, but the most important is if the technologies are able to trace the flows within in Mid Brabant, what the effects/impacts of tracing flows for the CE in Mid Brabant are?
Another worthful outcome is that the smart application areas (services, industry and logistics) of Midpoint Brabant can contribute the new entity MBC. By using the relevant currently available data within these application areas, a foundation can be built for the data lake.
This research is a valuable first step towards a more data driven and sustainable Mid Brabant.

Validity
While conducting the research, a COVID-19 pandemic occurred. It was more difficult to organise meetings and interviews, so the derived information is mostly based on desk research. There was also not much in-company knowledge about the research topic. This was clear from the start of the research, because this research functions as an exploration to discover the possibilities of data driven technologies and the CE in Mid Brabant. The available literature was up to date and a lot of research is currently being done on this topic.
The regional information for Mid Brabant was not always available. In this case information of the province North Brabant is used. For example, the potential of the data economy is given on a province level and the information on the level of Mid Brabant is lacking. In an ideal research situation, all information should be based on the level of Mid Brabant.
Due to the lack of literature about smart rural areas (Mid Brabant is mostly rural, with several urbanized spots), literature for smart urbanized areas is used. This literature is mostly about tracking flows in cities. However, the flows in rural areas are quite similar, but in lower quantity and less fast.
The research included programmes and projects from Midpoint Brabant. This is done with a purpose. Starting a data driven ecosystem from scratch is much harder than including familiar programmes and projects in it. The implementation time will also be less. The communication and standardisation within the data driven ecosystem is essential. By creating the network and the platform the work is not done and without co-evolution the network and the platform become useless. Despite the above-mentioned limitations, this explorative research was a valuable first step towards a circular and data driven Mid Brabant.

Feasibility data driven ecosystem
In this sub paragraph the feasibility of the proposed data driven ecosystem is reviewed. The economic priorities mentioned in the results of sub question 1, are in line with the proposed data driven ecosystem. On a province scale, the goal is to be one of the top five most innovative regions in Europe. One highlighted sector is high tech systems and materials. The data driven ecosystem can contribute to this sector and will contribute to the traceability of material flows within the province. On the scale of Mid Brabant, the economic priorities are mainly working on a smart economy and a smart society. The data driven ecosystem can contribute to a regional smart economy and as mentioned in the sub paragraph Midpoint Brabant - smart services, a smart society thrives by open data bases, such as the data lake (appendix 5).

The situation on the labour market is changing. As mentioned in the results of sub question 2, routine jobs will cease to exist and due to the technological developments, the jobs will become more complex. It is necessary to create educational tracks to cope with this changing situation. In addition, the current status on the labour market in both the industrial and ICT sector is tense. However, the Skills lab project, mentioned in the smart industries programme, is partly solving these changing situations.
The political situation in North Brabant has been changed in May 2020. Within the new policy agreement, the CE and digitalisation are mentioned in separate paragraphs, the link between the topics is not mentioned.
The potential of the data economy in North Brabant in 2020 is predicted around €746 million. To increase this number and to achieve the full potential, collaboration is needed (results 2). The component co-evolution of data driven ecosystem is taking this collaboration into account. In addition to collaboration makes co-evolution cross sector data sharing possible.
As mentioned in results 1, in Mid Brabant and the surrounding areas there are enough research institutes established which are focussed on relevant topics such as datafication (JADS), human behaviour and technology (MindLabs), advanced society (Tilburg University), high-tech industry (Technical University Eindhoven). These research institutes have the means and knowledge to be the engine behind the data economy in Mid Brabant.
Based on the results, there is support for a data driven ecosystem. However, educating, guiding and facilitating the quadruple helix organisations to participate in this data driven ecosystem is necessary to take the thresholds away.

6.0 Conclusions and recommendations

6.1 Conclusion

The main aim of this research is to develop an answer to the main question: *How can data driven technologies from the 4th industrial revolution contribute to the circular economy in Mid Brabant and Midpoint Brabant Circular?* To formulate the answer on this main question, sub questions are created. These sub questions are researched by qualitative methods with the answers on this sub questions are described underneath. The combined answers on the sub question will answer the main question.

Current situation in the ecosystem Mid Brabant

- The population in Mid Brabant will rise up to 430.000 by the year 2040, considering the trend of inhabitants moving to the more urbanized areas in Mid Brabant. The upcoming years the amount of 65+ people will go from 470.000 to 730.000 in 2040 in North Brabant.
- There are multiple research institutes in North Brabant, which can research this specific topic. These research institutes have the means and knowledge to be the engine behind the data economy in Mid Brabant.
- The overall labour market in Mid Brabant is increasing. The jobs in the ICT sector have increased by 4,5% and ICT jobs in Mid Brabant are underrepresented compared to the Netherlands. The amount of jobs in the industry sector remain stable and the sector is overrepresented compared to the Netherlands.
- The economic priority on the province scale is to be one of the top five most innovative regions in Europe. The economic priorities on the scale of Mid Brabant are first, working on a smart society with social and ecological added value. Second, working on a smart economy with a high economic efficiency. Third, the main value drivers are; knowledge, skill and character for sustainable development of our smart economy and smart society. The political situation in North Brabant has changed in May 2020. Within the new policy agreement, the CE and digitalization are mentioned in separate paragraphs. The link between these two topics are not mentioned.
- The potential for a data economy is present in the province of North Brabant. The percentage of market share for North Brabant compared to the Netherlands is roughly 13%. This percentage is a significant share of the whole market. By collaborating (cross sectors) the full potential of the data economy can be achieved. On the other hand, the majority (93%) of the companies in North Brabant foresees obstacles with the major obstacle being the insufficient knowledge concerning the topic.
- The hubs in Mid Brabant are an important source for topic specific information. The most important hubs on data and circular aspects are, JADS, Gate2 an MindLabs.

Data driven programmes of the closed involved organisations

- The smart services programme is meant to be the programme which provides tools for the other smart programmes of Midpoint Brabant. For example, a tool could be a data lake (appendix 5). Data driven technologies are applied in order to gain economic growth. However, data driven technologies can be applied to improve society and to tackle urgent social tasks.
- In the smart industry programme a lot of data driven technologies from the 4th industrial revolution are present. The potential of the 4th industrial technologies will help to establish an CE. First, these technologies are helpful to increase the resource efficiency. Second, better utilization of assets. Third, human capital is the driving force behind the 4th industrial technologies, but the need for certain skills is shifting to different competences. Fourth, the management of inventories will be simplified by the technologies of the 4th industrial revolution. Fifth, the quality of products will increase as well as their lifecycle. Sixth, matching demand and supply.

- The smart logistics programme has three valuable projects. The first valuable project is the DALI project where the aim of the project is to process, analyse and connect the collected data. This will lead to new insights, patterns and mutual connections. The second project is Pitch Logistics. Start-ups can pitch their innovative solution for a logistic problem. Also, challenges are subscribed from logistic entrepreneurs and these challenges need to be solved by the market. The last programme is the Logistic Academy. This academy is the linking pin between the logistic sector and the educational organisations. Better connection with the sector, will lead to more efficient educational tracks and an increase in human capital.
- The circular projects of MOED like, BioVoice and S4G are frontrunners and the collected data is the foundation to build upon. S4G is based on the thoughts of industrial symbiosis. BioVoice is a project where large companies can challenge the market for an internal circular problem. The smaller companies which are claiming to have the circular solution are becoming visible for the project team.
- Other relevant companies are JADS, MindLabs and Floow2.

Data driven ecosystem

- Based on the distinction of data driven technologies (data collection, data analysis and data integration) an overview is conducted what is present in Mid Brabant and what not, to create a data driven ecosystem. For data collection the present activities S4G, DALI, Gate2, BioVoice and Hubs can be used. Also, the absent activities such as IoT and RFID can be used for the data collection. For both the data analyses and data integration technologies are no present activities available.
- The data driven ecosystem consist out of three components; the network, the platform and co-evolution. The network consists out of a loose network of actors. All these actors must produce value for the ecosystem and all actors can extract data from the ecosystem. The platform provides the actors of the data driven ecosystem with tools, services and technologies that can be used to generate benefits. The platform makes it possible to contribute as an actor to the data driven ecosystem. In this case the platform will provide tools, services and technologies for circular business models, circular design questions, (waste) material flow, product flow, (reverse) logistic patterns and topic specific information from the hubs. The last component of the data driven ecosystem is co-evolution where being part of the data driven ecosystem demands connection between the actors. The full potential of the data economy can be achieved by collaborating (cross sectors).

To answer the main question of this research: *How can data driven technologies from the 4th industrial revolution contribute to the circular economy in Mid Brabant and Midpoint Brabant Circular?* The data driven technologies from the 4th industrial revolution can be contributing to the CE in many ways. The most important technologies are; IoT, BDA, RFID, AI and integration systems. By combining these technologies, the current relevant activities and the quadruple organisations, a data driven ecosystem can be formed in Mid Brabant. MBC can facilitate the data driven ecosystem by creating a platform, a network and co-evolution.

6.2 Recommendations

The recommendations are divided for the three application areas of Midpoint Brabant and general recommendations are formed for MBC itself.

Midpoint Brabant - smart services:

- The first recommendation is to increase the digitalisation status of small and medium enterprises in Mid Brabant. A (semi) governmental organisation as Midpoint Brabant has to take a leading role in this process. The smart services programme can facilitate this process by organising seminars, webinars, tools and services for entrepreneurs.

- Second, the programme should facilitate the data lake by (out sourced) research, budget and collaboration. The data lake should be an open source data base (available for students, researchers, businesses and society), open data bases are helpful for fasten (social) innovation. Data availability should be the cornerstone of the smart services program, especially data such as, condition, availability, location, usage time, used materials in products, by-products from other industrial systems etc.
- Last, focussing on an advanced/smart society in collaboration with MindLabs and Tilburg University. It is important to not only apply data driven technologies for economic growth, but also to improve society and tackle social tasks.

Midpoint Brabant – smart industries

- First, by sharing the already gathered valuable data (for CE) on the Gate2 campus with the data lake. This data can be the foundation of the data lake.
- Second, to fasten the transition to a CE the smart industries programme can contribute by stimulating retrofitting the current production machines with smart tools and sensors. The financial threshold will be much lower by adjusting the current production machines instead of purchasing new ones.
- Last, encouraging entrepreneurs to equip their products, materials or components with RFID or IoT. This can be accomplished by educating the entrepreneurs, showing them the (financial) advantages and in collaboration with Floow2.

Midpoint Brabant – smart logistics

- First, sharing the gathered data from the DALI project with the data lake. This data should be helpful to get an overview of the current logistic patterns. This overview is necessary as a basepoint, from this basepoint future logistics patterns can be developed, for example to facilitate reverse logistics.
- Second, reverse logistics is a major component of how the CE functions and a lot of practical issues occur while implementing it. The project Pitch logistics should subscribe more circular related logistic challenges to solve these issues or should outsource this to the BioVoice project.
- Third, rearranging the logistics sector to facilitate the CE is one of the most challenging system changes humanity will create. Including practicable circular challenges into logistics education is a great opportunity to facilitate this changing system.
- Last, encouraging entrepreneurs to equip their products, materials or components with RFID or IoT. This can be accomplished by educating the entrepreneurs, showing them the (financial) advantages and in collaboration with Floow2.

Midpoint Brabant Circular

- First, taking a leading role by implementing the technologies from the 4th industrial revolution for the CE. Organise meetings, short educational tracks or webinars to address the potential of these technologies in relationship with the CE.
- Second, standardisation of data is essential for usage. Organising research for standardisation circular related data, this research can be done by JADS in collaboration with the institutes which are responsible for standardisation.
- Third, searching students (JADS, Tilburg University, MindLabs) which could execute the follow-up research. Examples for follow-up research includes, effects and impacts of tracing flows for the CE, behaviour of organisations (potential actors) towards the data driven ecosystem, researching an applied case of RFID and IoT, research to the best digital architecture of the data driven ecosystem, the changing environmental impact due to these technologies etc.
- Last, organising the data driven ecosystem. The network needs to be established in collaboration with the applications areas of Midpoint. The platform (and dashboard) should be integrated in the portal (one-stop-stop) function. The co-evolution can be started with

internal data sharing (between Midpoint application areas). When the internal data sharing is arranged properly, extend the data sharing with external quadruple helix organisations.

References

Bloem et al. 2014. The fourth industrial revolution. Sogeti. Visited on: 12-02-2020. Retrieved from: www.sogeti.com/global/special/sogeti-things3en.pdf

Blunck, E. Werthmann, H. Industry 4.0 – An opportunity to realize sustainable manufacturing and its potential for a circular economy. Visited on: 03-04-2020. Retrieved from: https://hrcak.srce.hr/187419

BrabantAdvies. 2020. Werken aan een beter Brabant- jaar rapportage 2019. Visited on: 01-05-2020. Retrieved from: https://www.brabantadvies.com/wp-content/uploads/2020/04/Jaarverslag-2019-BrabantAdvies-def.pdf

BrabantAtlas. 2019. Atlas Bedrijvigheid (midden Brabant). Visited on: 31-05-2020. Retrieved from: https://etil.maps.arcgis.com/apps/MapSeries/index.html?appid=aef67f43c34e4eaf8e075c27c551a1d6

Chiapetta Jabbour, C. Lopes de Sousa Jabbour, A. Sarkis, J. Godinho Filho, M. Unlocking the circular economy through new business models based on large scale data: An integrative framework and research agenda. Visited on: 21-04-2020. Retrieved from: https://www.sciencedirect.com/science/article/pii/S0040162517308363

Davis, C, Aid, G. Zhu, B. 2017. Secondary Resources in the Bio-Based Economy: A Computer Assisted Survey of Value Pathways in Academic Literature. Visited on: 21-04-2020. Retrieved from: https://link.springer.com/article/10.1007/s12649-017-9975-0

De Mauro, A. Greco, M. Grimaldi, M. 2015. What is big data? A consensual definition and a review of key research topics. Visited on: 20-04-2020. Retrieved from: http://big-data-fr.com/wp-content/uploads/2015/02/aip-scitation-what-is-bigdata.pdf

Earth overshoot day. 2020. Earth overshoot day 2020. Visited on: 29-05-2020. Retrieved from: https://www.overshootday.org

Ellen MacArthur Foundation. 2019. Artificial intelligence and the circular economy – AI as a tool to accelerate the transition. Visited on: 12-02-2020. Retrieved from: http://www.ellenmacarthurfoundation.org/publications

Ellen MacArthur foundation. 2016. Intelligent assets: Unlocking the circular potential. Visited on: 12-02-2020. Retrieved from: https://www.ellenmacarthurfoundation.org/assets/downloads/publications/EllenMacArthurFoundation_Intelligent_Assets_080216.pdf

Esposito, M. Tse, T. Soufani, K. 2017. Reverse logistics for postal services within the circular economy. Visited on: 17-04-2020. Retrieved from: https://onlinelibrary.wiley.com/doi/full/10.1002/tie.21904?casa_token=36kxzQPs7mMAAAAA%3ACW8hKdV3XhB0o_j-zu-QJv8XJ_wYP0xfP9Y7guUYuYDfDCAYNRrlZ-br4AMxQsDCHzw6l2tvCVk9GsBDCQ

Floow2. 2020. About us. Visisted on: 01-06-2020. Retrieved from: https://www.floow2.com/about-nl.html

Franquesa, D. Navarro, L. 2018. Devices as a Commons: limits to premature recycling. Visited on: 21-04-2020. Retrieved from: https://dl.acm.org/doi/pdf/10.1145/3232617.3232624

Gupta, S. Chen, H. Hazen B. Kaur, S. Santibanez Gonzalez, E. 2018. Visited on: 21-04-2020. Retrieved from:
https://www.researchgate.net/profile/Shivam_Gupta30/publication/325890106_Circular_Economy_and_Big_Data_Analytics_A_Stakeholder_Perspective/links/5ba53d7992851ca9ed1c70fd/Circular-Economy-and-Big-Data-Analytics-A-Stakeholder-Perspective.pdf

Hammarberg, K. Kirkman, M. Lacey, S. 2016. Qualitative research methods: when to use them and how to judge them. Visited on: 18-05-2020. Retrieved from:
https://academic.oup.com/humrep/article/31/3/498/2384737

Hobson, K. 2015. Closing the loop or aquaring the circle? Locating generative spaces for the circular economy. Visited on: 15-05-2020. Retrieved from:
https://journals.sagepub.com/doi/abs/10.1177/0309132514566342

Homrich, A. Galvao, G. Abadia, L, Carvalho, M. 2018. The Circular umbrella: Trends and gaps on integrating pathways. Visited on: 15-05-2020. Retrieved from:
https://www.sciencedirect.com/science/article/pii/S0959652617327221

ING. 2019. Midden-Brabant – facts and figures. Visited on 31-05-2020. Retrieved from:
https://www.ing.nl/zakelijk/kennis-over-de-economie/jouw-provincie/regios-met-elkaar-vergeleken/factsheets-regio/factsheet-midden-brabant.html

JADS. 2020. About us. Visited on: 18-05-2020. Retrieved from: https://www.jads.nl/aboutus.html

Kantar Public. 2018. Kunstmatige intelligentie. Visited on: 18-02-2020. Retrieved from:
https://www.rijksoverheid.nl/documenten/rapporten/2018/11/30/kunstmatige-intelligentie

Kas, J. Bet, B. Truijens,D. 2017. Barriers and best practices for the circular economy. SMO promovendi – circular minds 2017/2018. Visited on: 24-02-2020. Retrieved from:
https://webcache.googleusercontent.com/search?q=cache:X9nwPtIIts4J:https://repub.eur.nl/pub/105039/Barriers-and-Best-Practices-for-the-Circular-Economy.pdf+&cd=13&hl=nl&ct=clnk&gl=nl

Kool, L. J. Timmer, L. Royakkers en R van Est. 2017 Opwaarderen – Borgen publieke waarden in de digitale samenleving. Rathenau Instituut. Visited on 18-02-2020. Retrieved from:
https://www.rathenau.nl/sites/default/files/2018-02/Opwaarderen_FINAL.pdf

Kusiak, A. 2017. Smart manufacturing. Visited on: 21-04-2020. Retrieved from:
https://www.tandfonline.com/doi/full/10.1080/00207543.2017.1351644

Lieder, M. Rashid, A. Towards circular economy implementation: A comprehensive review in context of manufacturing industry. Visited on: 24-05-2020. Retrieved from:
https://www.researchgate.net/publication/287972754_Towards_Circular_Economy_implementation_A_comprehensive_review_in_context_of_manufacturing_industry

Li, J. Tao, F. Cheng, Y. Zhoa, L. 2015. Big data in product lifecycle management. Visited on: 21-04-2020. Retrieved from: http://www.samiagamoura.com/_media/4.-paper-big-data-product.pdf

Manyika, J. Chui, M. Groves,P. Farell, D. Van Kuiken, S. Almasi Doshi, E. Open data unlocking innovation and performance with liquid information. Visited on: 30-03-2020. Retrieved from:

https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/McKinsey%20Digital/Our%20Insights/Open%20data%20Unlocking%20innovation%20and%20performance%20with%20liquid%20information/MGI_Open_data_FullReport_Oct2013.ashx

Mazhar Rathore, M, Anand Paul, Awais Ahmed, Suengmin Rho. Urban planning and building smart cities based on the internet of things using big data analytics. Visited on: 25-05-2020. Retrieved from: http://tarjomefa.com/wp-content/uploads/2017/04/6427-English-TarjoeFa.pdf

McKinsey. 2016. Stifterverband fur die Deutsche wissensschaft – Hochschul Bildungsreport. Visited on: 06-04-2020. Retrieved from: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=2ahUKEwjX8NnPstPoAhVRDuwKHdwCAvwQFjABegQIARAB&url=https%3A%2F%2Fwww.stifterverband.org%2Fmedien%2Fhochschul-bildungs-report-2020-bericht-2016&usg=AOvVaw1Bl8-PZqi0GLNgAtG9k0AW

MindLabs. 2020. About MindLabs. Visited on: 26-05-2020. Retrieved from: https://www.mind-labs.nl/mind-labs/

Moss Kanter. 2012. Harvard business review. Ten reasons people resist change. Visited on: 07-02-2020 Retrieved from: https://hbr.org/2012/09/ten-reasons-people-resist-chang

Oliveira, M.I.S., Loscio, B.F. 2018. What is a Data Ecosystem?. Visited on: 08-04-2020. Retrieved from: https://dl.acm.org/doi/pdf/10.1145/3209281.3209335

Pagoropoulos et al. 2017. The emergent role of digital technologies in the circular economy: A review. Visited on: 12-02-2020. Retrieved from: www.sciencedirectassets.com/282173/1

Pappas, I. Jaccheri, L. Mikalef, P. Giannakos, M. Social innovation and social entrepreneurship through big data: developing a research agenda. Visited on: 30-03-2020. Retrieved from: https://ntnuopen.ntnu.no/ntnu-xmlui/bitstream/handle/11250/2493000/MCIS2017_SUBMISSION_CR_.pdf?sequence=1&isAllowed=y

Philbeck, T. Nicholas, D. Engtoft Larsen, A.M. 2018. Values, ethics and innovation – Rethinking technological development in the fourth industrial revolution. World Economic Forum. Visited on: 18-02-2020. Retrieved from: https://italyexpo2020.it/expofiles/2018/11/No_Index_WEF_WP_Values_Ethics_Innovation_2018-1-18.pdf

Phills, J. Deiglmeier, K. Miller,T. 2008. Rediscovering social innovation. Visited on: 01-04-2020. Retrieved from: https://ssir.org/articles/entry/rediscovering_social_innovation

Province North Brabant. 2020. Bestuursakkoord 2020-2023. Visited on: 18-05-2020. Retrieved from: https://webstorage.onlinepublisher.nl/provincie-noord-brabant/publications/a3977662-5326-4517-b72b-c015305ed9a2/original.pdf

Province North Brabant. 2019. Bouwstenennotie circulaire economie 2019-2028-Brabant beweegt in kringlopen. Visited on: 25-02-2020. Retrieved from: https://www.brabant.nl/-/media/8d4e640318f94405b9d73a78d848119e.pdf

Province North Brabant. Circulaire economie. Visited on: 07-02-2020. Retrieved from: https://www.brabant.nl/onderwerpen/economie-en-werk/circulaire-economie

Province North Brabant. 2017. De bevolkings- en woningbehoefteprognose Noord-Brabant – Actualisering 2017. Visited on: 29-04-2020. Retrieved from: https://bevolkingsprognose.brabant.nl

Province North Brabant. 2020. Economisch programma Brabant 2020. Visited on: 26-05-2020. Retrieved from: https://www.brabant.nl/subsites/brabantvernieuwt

Province North Brabant. 2017. Marktanalyse dataficatie Brabant- economische groei met data. Visted on: 21-02-2020. Retrieved from: https://www.bom.nl/uploads/content/file/Smart%20Data%20Brabant_1535968671.pdf

Province North Brabant. 2017. Innovatie programma high-tech systemen & materialmen – uitvoeringsporgramma 2017-2020. Visited on 24-02-2020. Retrieved from: https://www.brabant.nl/bestuur/provinciale-staten/statenstukken/ps-dossier/dossier-economische-programma-brabant-2020?sort=nameasc

Ramados, T. Alam, H. Seeram, R. 2018. Artificial intelligence and Internet of Things enabled Circular Economy. Visited on: 21-04-2020. Retrieved from: http://www.theijes.com/papers/vol7-issue9/Version-3/I0709035563.pdf

Rajput, S. Praksash Singh, S. 2019. Connecting circular economy and industry 4.0. Visited on 22-04-2020. Retrieved from: https://www.researchgate.net/publication/332071510_Connecting_circular_economy_and_industry_40

RFID store. 2015. Examples of RFID asset tracking. Visited on: 29-05-2020. Retrieved from: https://www.atlasrfidstore.com/rfid-insider/rfid-asset-tracking-examples

Ripanti, E. Tjahjono, D. Fan, I. 2015. Circular economy in reverse logistics: Relationships and potential applications in product remanufacturing. Vistied on: 22-04-2020. Retrieved from: https://www.researchgate.net/profile/Benny_Tjahjono/publication/282007254_Circular_Economy_in_Reverse_Logistics_Relationships_and_Potential_Applications_in_Product_Remanufacturing/links/5601387e08ae07629e52bd09.pdf

Rood, L , Hanemaaijer, A. 2017. Waarom een circulaire economie?. PBL. Visited on: 21-02-2020. Retrieved from: https://themasites.pbl.nl/circulaire-economie/#

Rood, L. Kishna, M. Dassen, T. Dignum, M. Hanemaaijer, A. Prins, A. Reudink, M. 2019. PBL. Circulaire economie in kaart. Visited on: 22-04-2020. Retrieved from: https://www.pbl.nl/sites/default/files/downloads/pbl-2019-circulaire-economie-in-kaart-3401_0.pdf

Salminen, V. Ruohomaa, H. Kantola, J. 2017. Digitalization and big data supporting responsible business co-evolution. Visited on: 24-05-2020. Retrieved from: https://link.springer.com/chapter/10.1007%2F978-3-319-42070-7_96

Sauve, S. Bernard, S. Sloan, P. 2015. Environmental sciences, sustainable development and circular economy: Alternative concepts for trans-disciplinary research. Visited on: 15-05-2020. Retrieved from: https://www.sciencedirect.com/science/article/pii/S2211464515300099

Schütz, F. Heidingsfelder,ML. Schraudner,M. Co-shaping the future in quadruple helix innovation systems: uncovering public preferences toward participatory research and innovation. Visited on: 30-05-2020. Retrieved from: https://www.sciencedirect.com/science/article/pii/S2405872618301394

Song, B. Yeo, Z. Kohls, P. Hermann, C. 2017. Industrial Symbiosis: Exploring Big-data Approach for Waste Stream Discovery. Visited on: 21-04-2020. Retrieved from: ttps://pdf.sciencedirectassets.com/282173/1-s2.0-S2212827117X00036/1-s2.0

Song, Z, Moon, Y. 2016. Assessing sustainability benefits of cyber manufacturing systems. Visited on: 06-04-2020. Retrieved from: http://link.springer.com/10.1007/s00170-016-9428-0

Stock, T , Seliger, G. Opportunities of sustainable manufacturing in industry 4.0. Visited on: 06-04-2020. Retrieved from: https://www.sciencedirect.com/science/article/pii/S221282711600144X

Sukhdev, A , Vol, J , Brandt, K , Yeoman, R. Cities in the circular economy: The role of digital technology. Visited on 20-02-2020. Retrieved from: https://www.ellenmacarthurfoundation.org/assets/downloads/Cities-in-the-Circular-Economy-The-Role-of-Digital-Tech.pdf

Upadhayay, S. 2019. Transition from linear to circular economy. Visited on: 24-02-2020. Retrieved from: https://www.researchgate.net/publication/336243057_Transition_from_Linear_to_Circular_Economy/link/5d967a32458515c1d391b6ec/download

Weinstein, R. 2005. RFID: A technical overview and its application to the entreprise. Visited on: 20-04-2020. Retrieved from: https://www3.cs.stonybrook.edu/~jgao/CSE370-spring07/RFID.pdf

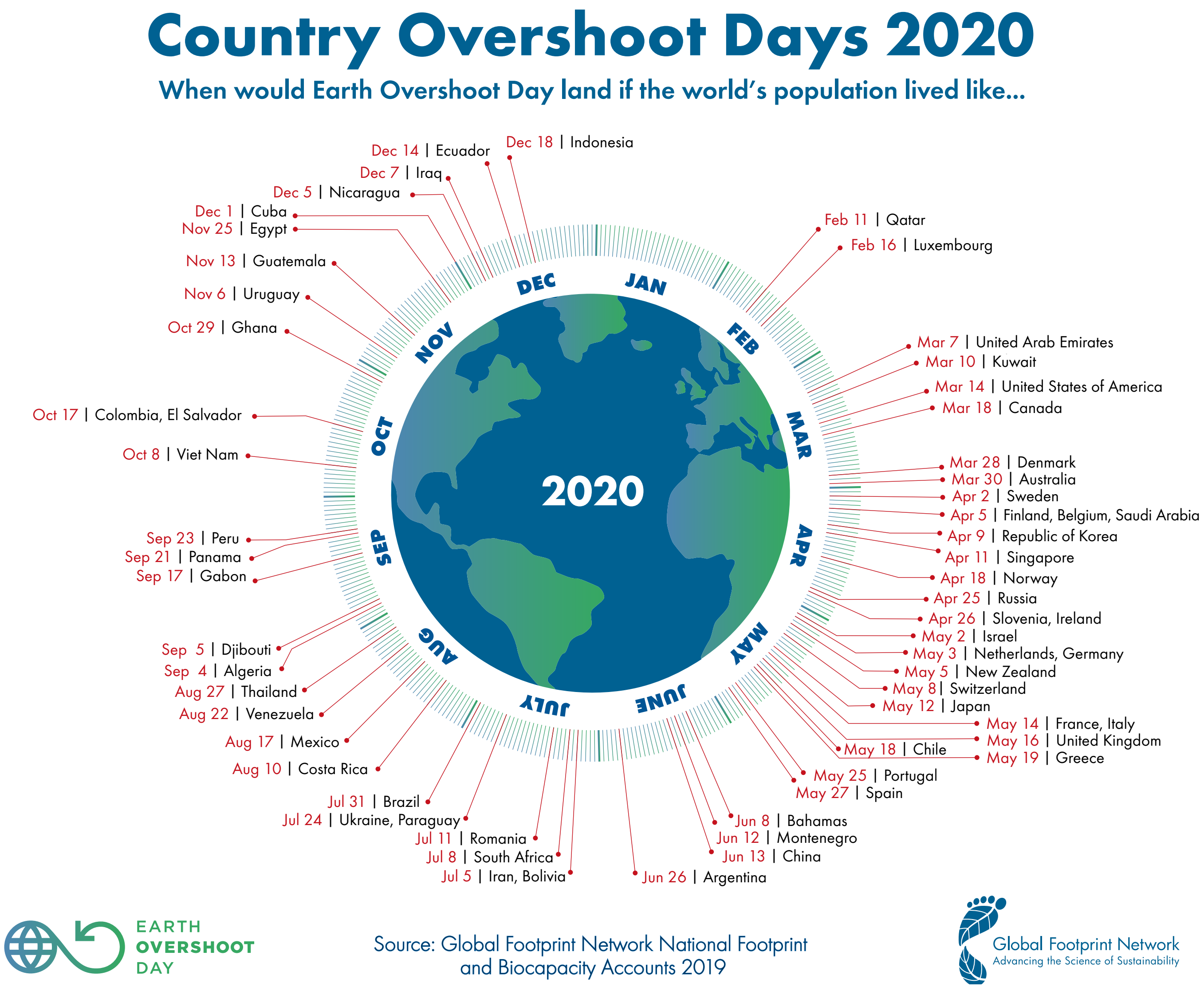
WijZIjnTilburg. 2018. Kaart-midden-Brabant. Visited on: 30-05-2020. Retrieved from: https://www.wijzijntilburg.nl/9-redenen-waarom-tilburg-de-hoofdstad-van-brabant-is/kaart-midden-brabant/

World Economic Forum (in collaboration with Accenture Strategy). 2019. Visited on: 21-04-2020. Retrieved from: https://www.researchgate.net/profile/Ari_Happonen/publication/337170902_Key_Enablers_for_Deploying_Artificial_Intelligence_for_Circular_Economy_Embracing_Sustainable_Product_Design_Three_Case_Studies/links/5dda8024299bf10c5a2e7d55/Key-Enablers-for-Deploying-Artificial-Intelligence-for-Circular-Economy-Embracing-Sustainable-Product-Design-Three-Case-Studies.pdf

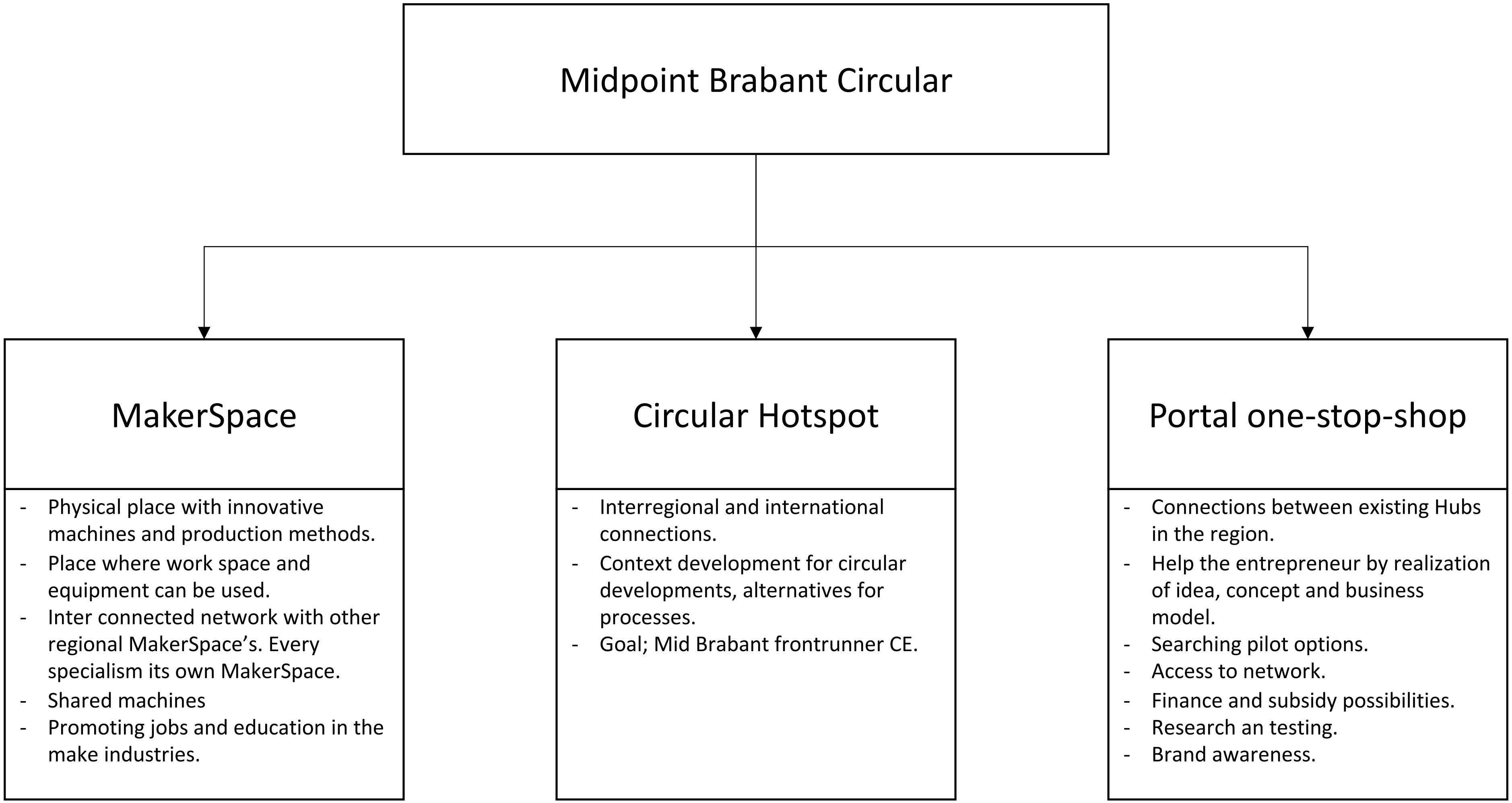
Zicari, R. 2014. Big data: challenges and opportunities. Visited on: 02-04-2020. Retrieved from: http://www.odbms.org/wp-content/uploads/2013/07/Big-Data.Zicari.pdf

Appendices

1.0 Earth overshoot days 2020



2.0 Functions Midpoint Brabant Circular



3.0 Demographics

	bevolking	bevolkingsgroei				bevolking
	2017	2017-2024	2025-2039	2040-2049	2017-2049	2050
Noord-Brabant	2.513.700	70.600	61.800	-7.600	124.900	2.638.500
Stedelijke concentratiegebieden	1.765.000	62.600	74.800	20.200	157.600	1.922.600
Landelijke gebieden	748.700	8.100	-13.100	-27.700	-32.700	715.900
RRO West-Brabant	699.600	16.600	7.500	-7.900	16.300	715.900
RRO Midden-Brabant	400.800	13.000	15.400	3.500	32.000	432.800
RRO Noordoost-Brabant	651.200	17.500	16.700	-4.000	30.200	681.400
RRO Zuidoost-Brabant	762.100	23.500	22.100	700	46.300	808.400

4.0 Circular companies in Mid Brabant

	Bedrijfsnaam	***Plaats***	***Website***	***Regio***	***Sector***
1	AGC Nederland BV	Tilburg	https://www.agcnederland.nl/glashandel/tilburg/	Midden Brabant	Recycling (Glas handel)
2	Agristo	Tilburg	https://www.agristo.com/en	Midden Brabant	Food
3	Ahrend	Sint-Oedenrode	https://www.ahrend.com/	Oost Brabant	Maak industrie (meubels)
4	Ardagh group	Dongen	https://www.ardaghgroup.com/#!corporate	Midden Brabant	Recycling (Glas handel)
5	Arno van den Dungen	Heusden	https://www.arnovddungen.nl/	Midden Brabant	Recycling
6	Aterro	Tilburg	https://www.attero.nl/nl/onze-locaties/tilburg/	Midden Brabant	Recycling
7	BAT	Tilburg	https://www.bat.nl/	Midden Brabant	Recycling
8	Brekelmans schoenen	Bovenkarspel	https://www.brekelmansschoenen.nl	Noord-Holland	Textiel (schoenen)
9	Bruggenbank	Nederland	https://www.bruggenbank.nl/	Nederland	Platform
10	Broodje Poep	Nederland	https://www.broodjepoep.com/	Nederland	Food
11	Capi	Tilburg	https://www.capi-europe.com/	Midden Brabant	Maak industrie (plantenbakken)
12	Cheaque	Tilburg	https://www.cheaque.com	Midden Brabant	Detailhandel (textiel)
13	Coolrec	Waalwijk	https://www.coolrec.com/nl-nl	Midden Brabant	Recycling
14	CVB recycling	Tilburg	https://www.cvbecologistics.com/	Midden Brabant	Recycling
15	De afval spiegel	Tilburg	https://www.deafvalspiegel.nl/	Midden Brabant	Advies bureau
16	De Hamer beton	Waspik	https://www.dehamer.nl/	Midden Brabant	Maak industrie (beton)
17	De vergeten Appel	Biezenmortel	https://devergetenappel.nl/	Midden Brabant	Food
18	Delvers	Tilburg	https://delvers.online/	Midden Brabant	Advies bureau
19	Desh plantenbak	Tilburg	https://desch.nl/	Midden Brabant	Maak industrie (plantenbakken)
20	Desso	Waalwijk	http://www.desso.nl/	Midden Brabant	Maak industrie (tapijt)
21	DS Smith	Tilburg	https://www.dssmith.com/	Midden Brabant	Maak industrie (verpakkingen)
22	Eco dorp Boekel	Boekel	https://www.ecodorpboekel.nl/	Oost Brabant	Platform/showcase
23	Eerlijk winkelen	Tilburg	https://eerlijkwinkelen.nl/stad/index/59/Tilburg	Midden Brabant	Food
24	Enssieg groep	Tilburg	https://www.enssieg.nl	Midden Brabant	Bouw
25	Eseer Verpakkingen	Tilburg	https://www.esserverpak.nl	Midden Brabant	Maak industrie (verpakkingen)
26	Ewaste Arcadis	Eindhoven	https://www.ewastearcades.nl/	Oost Brabant	Onderwijs, recycling
27	Ewaste race	Eindhoven	https://www.ewasterace.nl/	Oost Brabant	Onderwijs, recycling

28	Gebruikte bouwmaterialen	Sint-Oedenrode	https://gebruiktebouwmaterialen.com/	Oost Brabant	Bouw
29	Greenwheels	Tilburg	https://www.greenwheels.com/nl/	Midden Brabant	Moiliteit
30	Goede speelprojecten	Tilburg	https://speelprojecten.nl/over-ons/certificaten	Midden Brabant	Maak industrie
31	Havep	Goirle	https://www.havep.com/nl-nl	Midden Brabant	Textiel
32	Heel Nederland deelt	Oisterwijk	https://www.heelnederlanddeelt.nl/nederland.html	Midden Brabant	Platform
33	Herso	Loosbroek	https://herso.nl/	Oost Brabant	Maak industrie (meubels)
34	Het Beginstation	Helmond	https://www.beginstation.nl/	Oost Brabant	Platform
35	Hopperpoint	Tilburg	https://hopperpoint.nl/nl/home	Midden Brabant	Moiliteit
36	IFF	Tilburg	https://www.iff.com/en	Midden Brabant	Food
37	Injection point	Moergestel	https://www.injection-point.nl/	Midden Brabant	Maak industrie (kunststof)
38	Isovlas	Oisterwijk	https://www.isovlas.nl/	Midden Brabant	Maak insdustrie (Isolatie)
39	Kerry group	Tilburg	https://www.kerrygroup.com	Midden Brabant	Food
40	Kreativiteit	Tilburg	https://circulair.com/item/kreativitijd/	Midden Brabant	Kunst
41	Kristels fashion	Tilburg	https://www.kristelsfashion.nl/	Midden Brabant	Detailhandel (textiel)
42	LDM	Drunen	https://www.ldmbrass.com/nl/home	Midden Brabant	Maak industrie (metalen)
43	Leapp	Breda	https://leapp.nl/pages/leapp-breda	West Brabant	Refurbish
44	Maakplaats Uden	Uden	https://maakplaatsuden.nl/wie-is-maakplaats-uden	Oost Brabant	Kunst
45	Mengfabriek	s-Hertogenbosch	http://www.mengfabriek.nl/	Oost Brabant	Platform
46	Moestuinles	Tilburg	https://tilburgcirculair.nl/item/moestuinles/	Midden Brabant	Kennis
47	Mood street	Breda	https://www.moodstreet.nl/	West Brabant	Detailhandel (textiel)
48	Natuchem	Tilburg	https://www.natuchem.eu	Midden Brabant	Recycling
49	Nederland kringloop	Nederland	https://allekringloopwinkels.nl/nederland	Nederland	Reuse
50	NoFoodWasted	s-Hertogenbosch	http://www.nofoodwasted.com/	Oost Brabant	Food
51	Ontboedel.nl	Tilburg	https://www.ontboedel.nl/	Midden Brabant	Reuse
52	Oude tenten naar schorten	Tilburg	https://futureproof.community/oplossingen/van-oude-tenten-naar-schorten	Midden Brabant	Recycling
53	Park sharing	Tilburg	https://www.parksharing.nl/parksharing.html	Midden Brabant	Platform
54	PC save	Tilburg	http://www.pcsave.nl/	Midden Brabant	Repair
55	Philtex	Tilburg	https://360group.nl/	Midden Brabant	Advies bureau

56	Plastival	Eindhoven	https://www.cultuureindhoven.nl/project/plastival/	Oost Brabant	Kunst
57	Plug in city	Eindhoven	https://www.plugincity.nl/	Oost Brabant	Platform
58	Q-lite	Baarle-nassau	https://www.q-lite.com/nl/	Midden Brabant	Maak industrie (Elekt apparaten)
59	Raak metals	Tilburg	https://www.raakmetals.nl/	Midden Brabant	Recycling
60	Remmers bouwgroep	Tilburg	https://www.remmersbouwgroep.nl	Midden Brabant	Bouw (lease)
61	Ruil winkel ypelaer	Tilburg	https://ruilwinkelypelaer.nl/	Midden Brabant	Platform
62	Schijvens	Hilvarenbeek	https://www.schijvens.nl/	Midden Brabant	Textiel
63	Scholle IPN	Tilburg	http://www.scholleipn.com	Midden Brabant	Maak industrie (verpakkingen)
64	Schoonste wijk	Tilburg	https://schonstewijk.weebly.com/	Midden Brabant	Collectief
65	Searious business	Eindhoven	https://www.seariousbusiness.com/	Oost Brabant	Maak industrie (verpakkingen)
66	Seats2meet	Tilburg	https://www.seats2meet.com/en	Midden Brabant	Platform
67	SHFT	Berkel enschot	http://www.shft.nl/	Midden Brabant	Advies bureau
68	Silgan Dispensing	Waalwijk	https://silgandispensing.com/our-locations	Midden Brabant	Maak industrie
69	Sock source	Tilburg		Midden Brabant	Textiel
70	Staal instruments	Waalwijk	https://staalinstruments.com/	Midden Brabant	Waste/water monitoring
71	Stadsmakers 013	Tilburg	https://stadsmakers013.nl/	Midden Brabant	Platform
72	StarSock	Oisterwijk	https://www.starsock.nl/	Midden Brabant	Textiel
73	Stiels	Veldhoven	https://www.stiels.eu/over-stiels	Oost Brabant	Bouw (lease)
74	Suez	Waalwijk	https://www.suez.nl/nl-nl	Midden Brabant	Recycling
75	Syncreon	Tilburg	https://www.syncreon.com/	Midden Brabant	Maak industrie
76	The Wasted Chef	Tilburg	https://www.thewastedchef.nl/	Midden Brabant	Food
77	Thinkle	Raamsdonkveer	https://www.thinkle.nl/	West Brabant	Advies bureau
78	To Good to Go	Tilburg	https://toogoodtogo.nl/nl	Midden Brabant	Food
79	Tosaf benelux	Tilburg	https://www.tosafbenelux.nl	Midden Brabant	Maak industrie (kunststof)
80	Tricorp	Reijen	https://www.tricorp.com/	Midden Brabant	Textiel
81	Tuinderij van Es	Haaren	https://tuindees.nl/	Midden Brabant	Food
82	Urban mining	Eindhoven	https://urbanminingcollective.nl/	Oost Brabant	Bouw
83	Van PET naar PRET	Tilburg	http://vanpetnaarpret.genietgroep.nl/	Midden Brabant	Onderwijs
84	Verbo	Tilburg	http://www.verbonet.com/#home	Midden Brabant	Recycling

85	Verhagen metaal recycling	Tilburg	https://www.verhagenmetaalrecycling.nl/home.html	Midden Brabant	Recycling
86	Vernooy textiel recycling	Tilburg	https://www.cvbecologistics.com/	Midden Brabant	Recycling
87	Vorselaar vruchtensappen	Tilburg	https://www.vorselaars.nl	Midden Brabant	Recycling
88	Voedspoor	Tilburg	http://www.013food.nl/projecten/meer-kennis/wat-eet-tilburg/	Midden Brabant	Food
89	Voor straks	Tilburg	https://voorstraks.nl/	Midden Brabant	Advies bureau
90	W&R etiketten	Tilburg	https://www.wr-etiketten.nl/	Midden Brabant	Maak industrie
91	We-re-use	Tilburg	http://we-re-use.nl/	Midden Brabant	Vrijwilligers organisatie
92	Wolkat	Tilburg	https://www.wolkat.com/	Midden Brabant	Textiel
93	Zuiderzwam	Tilburg	https://www.zuiderzwam.nl/	Midden Brabant	Food

5.0 Harvesting data for Midpoint Brabant Circular

Circular expertise in exchange for data (V1.1)