FACULTEIT ECONOMIE EN BEDRIJFSKUNDE

THE SUPPORTIVE ROLE OF INFORMATION SYSTEMS FOR COMPANIES IN THE TRANSITION TOWARDS A CIRCULAR ECONOMY

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Permission

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Foreword

After four years of studying economics at the University of Gent, this master's dissertation is a good ending for me before starting my working life. This master's dissertation became an excellent opportunity for me to link my theoretical knowledge to a growing and trending issue within the economy. Sustainability, and more specifically circularity, is gaining in importance and many companies have no idea how to tackle this in a constructive way.
Although the concept of circular economics was also included in our curriculum, in hindsight I knew very little about it. However, my interest was aroused because I am personally convinced that the circular economy is an excellent answer to the linear economy that presents many problems today. The circular fact is already present in biology, let's introduce it in economics as well!

For the best support within the transition of a company one cannot leave out the information technology of the company. My interest to what role the information system has given within circular economy evolved after an internship I did myself last year. This internship sparkled my interest in the technological aspects of an organisation and I am grateful that I was able to combine this interest with the transition towards a circular economy.

Unfortunately, I needed to work out this master's dissertation during the COVID-19 crisis. This does not have to pose a specific risk to the dissertation as sufficient information was already collected before the outbreak of the virus. The only possible consequence of this incident is that companies do not want or cannot agree on a second visit for the assessment and explanation of the diagrams, but there is a solution for everything so virtual meetings were proposed.

I would like to thank both my promoter and co-supervisor. Without the guidance of professor Renata Petrevska Nechkoska and professor Geert Poels I would not be able to deliver the dissertation in this quality. Special thanks to my mentor Renata for always being available for general questions and the extensive explanation of the DENICA method. Professor Poels is thanked for the constructive feedback on interim texts which upgraded the final text.
I would also like to thank the interviewees. Their input was crucial for the quality of the master thesis. I realise that it is not always easy to make time for these types of projects, so their valuable time and information is greatly appreciated.
Finally, I would like to thank everyone close to me, including my parents, for giving me this opportunity. Without their support, this could never have happened. I would also like to thank friends and family who were involved in brainstorming on the subject or proofreading the master thesis.

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List of used abbreviations

AUS: Adoption, Utilization and Success

BD: big data

BI&A: business intelligence and analyses

BI: business intelligence

BMC : business model canvas

CAD: computer-aided design

CBM : circular business models

CBMC : circular business model canvas

CE: circular economy

CIM: circular innovation models

COM: circular output models

CRM: customer relationship management

CSR : corporate social responsibility

CUM: circular use models

DSR : design science research

eg: example given

EMF: Ellen MacArthur Foundation

ERP: enterprise resource planning

EU: European Union

FP&A: financial planning and analyses

GSCM: green supply chain management

HR: human resources

IIoT: industrial internet of things

IS : information systems

IT: information technology

KPI: key performance indicators

LE : linear economy

PEOU: perceived ease of use

PU: perceived usefulness

SIDA: Sense, interpret, decide, act

SME: small medium enterprise

SNA: social network analysis

SWD: staff working document

TAM: technology acceptance model

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Abstract

This master thesis investigates the supportive role of an information system when companies would go from a linear to a circular design. The main purpose of this master thesis was to find a non-exhaustive list of information flows that the information system needs to deliver to its user(s) of a circular company. This could lead to some guiding directions for companies in the transition towards a circular economy.

This research is interesting because the circular economy can provide an answer to the environmental problems we are experiencing as it is more sustainable for our planet than the current linear economy. Additionally, the concept is more and more accepted by companies to integrate in their daily operations. An increased interest in the circular economy can also be observed among governments. However, a problem that exists is that nobody knows exactly how to implement the circular aspects. This research partially tries to fill this knowledge gap by examining the role of information systems in the circular economy. This research and knowledge gap may be present because it is a relatively new concept.
It has been proven that there are economic benefits to both the concept of circular economy and the use of information systems. With regards to circular economy, these aspects are studied separately, but the relationship between the two is not yet discussed in prior literature. However, this is necessary because in practice these two issues (CE and IS) are often combined and this could result in a competitive advantage.

The relationship among the different actors in the CE concept is sought by means of an extensive literature study and by means of interviews with some Belgian companies. Via the design science research and DENICA method a model of the actors, their role and interconnectivity, present within a circular business environment and the information flows between them was drawn up. In order to arrive at this model, an iterative method was applied in which first one's own findings, then the theory from literature and finally interviewed professionals were addressed.

The abovementioned model is a first, but not only contribution of this work. After applying the DENICA method specified on the role of IT and the circular process in the model, the information flows between them were listed. This resulted in the main contribution of this work: a non-exhaustive list of information flows for organizational teams that is considered necessary for enterprises in a circular economy.

Introduction

Increasing numbers of news articles confirm it: the way humans currently consume cannot be maintained indefinitely. Year after year the earth overshoot day falls earlier in the year and this is a problem. Fortunately there are also other articles that come up with solutions: the circular economy. The circular economy is a proposed replacement of the linear economy that is maintained today. Within governments, the concept is being put more and more on the political agenda. Unfortunately, no one knows exactly how we are going to implement it. This master thesis will partly provide an answer to this by examining the role of the information system within circular enterprises. The supporting role of information systems in companies within the (transition to) circular economy is interesting to investigate because companies combine these two aspects in order to achieve the best results.

It has been proven that there are economic to the concept of circular economy benefits (EMF, 2015; Morgan & Mitchel, 2015; Bastien et al., 2013). The same applies to the use of information systems (Bozic, 2018; Yang Z, et al. 2017; Beier et al., 2017; Ghobakhloo, 2019). With regards to circular economy, these aspects are studied separately, but the relationship between the two is not yet discussed in prior literature. However, this is necessary because in practice these two issues (CE and IS) are often combined and this could result in a competitive advantage (Green, 2012). This knowledge gap is addressed in my thesis. This master thesis investigates the supportive role of an information system when companies would go from a linear to a circular design. The main goal of this master thesis was to find a non-exhaustive list of information flows that touch upon different components across the business ecosystem that the information system should deliver to the user(s) of a circular company. Although companies might think that they know the information (Rizos, Behrens, et al., 2016), it is surely not the same as being able to collect and produce it, hence the managerial contribution of this master thesis. This master thesis answers the combination of *Lack of knowhow* and the *Lack of information* by stating which information flows should be gathered from which roles in the business ecosystem. This model makes it possible for organisations to not only know the needed information but also make it possible to produce it through their information system.

An information system should support the circularity of the organization and for that the IT should contain a number of components and be a fundamental part of diverse processes. The relationship among the different actors in the CE concept is sought by means of an extensive literature study and by means of interviews with some Belgian companies. Via the design science research (DSR) (Hevner

et al, 2004) a model was drawn up. In order to arrive at this final model, an iterative method was applied in which first one's own findings, then the theory from literature and finally the interviewed professionals were addressed (see attachment 6). When interviewing the companies, both companies that apply circularity and companies that work as partners within this fact were addressed.

This master thesis starts with explaining the research methodology. Afterwards, an extensive literature study that first examines the concept of circular economy and later also the concept of information systems is presented. Thirdly, the DSR plan is explained, resulting in the artifact description. Finally, the discussion of the findings, evaluation and conclusion are mentioned.

Research methodology

In this study, qualitative research was carried out to provide an answer to an existing research gap. This gap is the lack of information about the relationship between information systems and the circular economy.

For this purpose, both desk research and field research was iteratively conducted. The reason to do so is twofold; (1) literature on this topic is not yet mature and (2) through this iterative method the available literature findings and additions were tested in practice. The process started through a literature review. Afterwards, an iterative process between literature and interviews took place. The interviews were conducted with five companies that either carry out circular aspects themselves or help other companies to do so.

Data collection

For the desk research through literature review, scientific articles were searched in online data banks as Google Scholar, ScienceDirect and ResearchGate. Papers and white papers were searched about the two main topics with keywords such as 'circular economy', 'circular business model', 'role information systems', 'industry 4.0' and ‘data as resource’. This literature review formed the basis for the questionnaire used during the interviews (see attachment 2) and also to draw up the first model in combination with one's own knowledge (see attachment 6). The most important sources for this master thesis are sources that were published in well-known journals and could count on many citations.

Interviews answered the field research part of this thesis. Those interviews were only conducted with Belgian companies that were expected to have a role in the circular story. This assumption was made whether or not keywords such as ‘circularity’, ‘CSR’ or ‘sustainability’ could be found on the website of the companies in question and based on their products or services offered. The circularity of the addressed companies was later-on analysed by means of two different circular models. The

interviews were semi-structured, so that more information could be requested during the interviews if necessary. Notes were made during the interviews and the aim was to briefly summarise the interviews afterwards so that they would provide a clear overview and would be easier to compare. This made it possible to map out similar things more clearly.

Applied method

Literature

This research started with an extensive literature study. This resulted in two major compartments, respectively circular economics and information systems, and formed the foundation of the background section, the literature section and the questions used in the interviews to design the models. Concerning the circular economy section this research discussed why the transition from LE to CE is needed, how to look at CE, the main enablers and barriers and the most common business models. The information systems section in itself looked at the developments around industry 4.0, green information systems, the advantages of using them and the role of data as key resource. The inclusion criteria for this data is described in the data collection part.

Interviews

The intention was to interview at least 3 circular companies about the role of the information system within a circular process.

In order to find these companies, several companies were contacted by phone or e-mail with the question whether they wanted to participate in this interview. About fifty Belgian companies were considered as a possible target (see attachment 1). These fifty companies were selected based on the location of their head office, accessibility for the interviewer and the activities they carry out. All these companies were considered to be potentially circular based on the products offered. Within these fifty companies it was then estimated for each company whether they were effectively using a circular process by searching the company's website. In this search on the website, key words such as 'circularity', 'sustainability' and 'CSR' were looked for. This was not found on the site of about ten companies, which means that they are not supposed to carry out any circularity. This assumption was made as implementing circularity leads to a positive image for the company and therefore companies will certainly communicate this. In the end, about forty companies were contacted with the question whether they would participate in this research. Eight companies replied that they effectively apply circular aspects but only five of them wanted to make time for an interview, the other three referred to their website for more information. As the goal of the research was to specifically interview companies to get to know their processes in-depth, those three companies were left out. The other five companies asked for more information or showed a certain interest. Therefore, more explanation was given about the research and how this could positively influence both the research and the company, time and place for the interviews were arranged. A few days before the interview,

another email was sent with the purpose of the survey and a few questions that would be asked during the interview so that the interviewee would be optimally prepared. During each interview, the answers were notated and briefly summarized afterwards. The interviewee was given an explanation of the summary and, if necessary, could make additional comments to ensure that the summary was representative.

The considered circularity needed to be assessed. A systematic literature review by Rosa, Sassanelli & Terzi (2019) found that there are 3 macro segments in the classification of CBM's: the BMC of Osterwald and Peigneur (2010), the ReSOLVE framework proposed by the Ellen MacArthur Foundation (2015) or thirdly a hybrid model exploitation of the two previous models. This master thesis states that a company is circular if they have successfully implemented a circular business model. The interviewed companies in this master thesis were firstly analysed through the CBMC model of Lewandowski (2016) (see attachment 3) based on the BMC of Osterwald and Peigneur (2010) and secondly through the Butterfly diagram (EMF, 2017) (see attachment 4) which is based on the ReSOLVE framework (EMF, 2015). These models are each elaborated in the literature section as they are also used to support the first artifact. In most prior literature, circularity is assessed by applying one model. In order to counteract biased results, it was decided to use two different models. These had similar results and it was concluded that there was saturation and therefore no need to perform another analysis as this might lead to the same result. Hence the hybrid method was not applied and not discussed in this master thesis. In conclusion, the five interviewed companies were judged on their circularity using the Butterfly Diagram and the CBMC model, and three of them could be considered circular which answered the intention for this research.

Modelling

Design science

The proposed results in this master thesis answers the lack of knowledge about the relationship between the information systems and circular economy as this is not yet discussed in previous literature. However, this is necessary because in practice these two issues (CE and IS) are often combined and this could result in a competitive advantage (Green, 2012). This knowledge gap is addressed in my thesis. An information system should support the circularity of the organization and for that the IT should contain a number of components and should be fundamentally involved in diverse processes. In order to come to the answer to this question, the principles of design science (Hevner et al, 2004) were followed.

DSR is generally accepted as a legitimate approach in IS research and as this master thesis focuses on the role of IS in CE this approach was used. As described by Hevner and Gregor (2013) DSR can have multiple knowledge contributions. This master thesis answers to the level 1 knowledge contribution; Situated implementation of artifact; as this master thesis implements the DENICA method, hereafter

described, which results in a model of the actors, their role and interconnectivity, present within a circular business environment and the information flows between them. This model will eventually result in a non-exhaustive list of information flows for organizational teams that is considered necessary for enterprises in a circular economy. This model is described by Hevner and Gregor (2013) as prescriptive knowledge and can be seen as a new solution; the non-exhaustive list of information flows, for a known problem; *how to implement circular aspects in a company's information system?.* Thanks to the DENICA method the diagrams are clearly represented and the list of information flows is represented and communicated within the discussion section. Applying those information flows within the company's IS will increase the efficiency of its circular process, which will also make the company more competitive as the information system will provide concrete information for the managers to make their decisions, desirably, better.

Method

Design science is a search process (Hevner et al, 2004). An iterative method (see attachment 6) in which first the theory was addressed by means of a literature study, which, together with one's own knowledge, formed the basis for making a first model. This model was then adjusted via interviews with companies, thus also addressing practice. In between the interviews with the companies, the literature and therefore theory were briefly addressed. Literature, and thus theory, was thoroughly addressed a second time after all interviews had taken place. After this, a model was presented to the interviewed companies, who were then asked for feedback on this model. Two companies replied with the feedback that the model was representative for their process, and one of the two even made an additional remark, which led to a final adjustment of the model thanks to practical findings. It can therefore be stated that the model was evaluated throughout the interviews and after. Both theory and practice was implemented in the model.

The model itself was made based upon the DENICA-method (Petrevska Nechkoska, 2020), which is a method for managers that supports the adaptability of tactical management and its information systems. This method starts with identifying a system of roles and accountabilities, followed by mapping the information sensors, the information emitters and all risks related to the process. The last phase of the DENICA-method is the continuous performance of the Sense-Interpret-Decide-Act loop. The method is explained in the modelling section of this master thesis. The first phase of this method was answered by the literature and the interviews. The second, third and fourth step of this method was done by means of one's own findings, the field notes of the interviews and the knowledge acquired through literature. The use of this method answers the design science principle of research rigor (Hevner et al, 2004).

The final model was mailed to all the interviewed companies with the question if they wanted to give feedback on it concerning the points where the company itself experienced the most problems. After this, any changes to the model were made one last time with respect to the given feedback.

Background

Before the model can be drawn, it is necessary to introduce some concepts using relevant literature. First of all, the concept of CE is explained, followed by the second important concept of IS and the role they could play in the CE.

Circular Economy

Introduction

From Linearity to circularity

The economic environment as we know it, is mostly linear. This linearity finds his roots in the Industrial Revolution which increased prosperity substantially by radically increasing the productivity of the economy's factors of production – land, labour, and capital – through breakthrough technological advances (Ellen MacArthur Foundation, 2016). Henry Ford, for example, used labour diffusion -described by Adam Smith in his The Wealth Of Nations- to maximize productivity and profits through business continuity. The success of those companies were tremendous and this led other companies to do the same. The linear economy has a product life cycle described as take-make-sell-dispose (Ellen MacArthur Foundation, 2016), with a product at the end of his lifecycle. This way of working ruled the 20th century, but nowadays we see threats to this system. Uneven wealth distribution (Ellen MacArthur Foundation, 2013; Sariatli, 2017), extensive use of materials (Sariatli, 2017) and thus the risk of supply chain disruption (Ellen MacArthur Foundation, 2016), shortages of food for a growing demography (Sariatli, 2017; Ellen MacArthur Foundation, 2016), effects of climate change and the rising demand for environmentally sound products (Ellen MacArthur Foundation, 2016) are the biggest threats to the linear economy described in prior literature.
According to the comparative study of Sariatli (2017) those treats are this big that the natural environment is surpassing a tipping point where the world irreversibly loses its capacity to maintain the biosphere as we know it. The Earth Overshoot Day is the calculated illustrative calendar date on which humanity's resource consumption for the year exceeds Earth's capacity to regenerate those resources in that year. This day tends to fall earlier in the year than it used to do and this reflects the biggest problem of the linear economy. Those threats are the reason companies could want to change their way of working. It is feasible that multiple processes will no longer be possible in a couple of years, therefor companies need to look for an alternative: Circular Economy.

Short explanation about the topic

The phrase circular economy (CE) itself was introduced by Pearce and Turner (1989), although the concept has deep roots dating back to the 1960s. The topic as mentioned has been contributed by a large number of researchers, theorists and vocational parties. The research of Stahel (1982) mentioned alternatives to the fast-replacement system of the linear economy in order to increase the product life to insert an economic perspective. Stahel (1982) talked about the slow-replacement

system -which prolonged the design life of materials by using resistant materials ect.- and the self-replenishing system -which was based on a spiral loop flow of the materials. The self-replenishing system of Stahel was categorized as downcycling in later literature (Braungart and McDonough, 2007). The Cradle-to-Cradle principle, which additionally was introduced by Braungart and McDonough (2008), is an example of upcycling. The latter consists of "metabolisms" that enables materials to maintain their status as resources and accumulate intelligence over time (Braungart & McDonough, 2007). The circular economy has been defined by many people and several papers are proposing different definitions. For this master thesis, the used definition for circular economy is the one described by the Ellen MacArthur Foundation (2013):

"an industrial economy that is restorative or regenerative by intention and design"

This definition is commonly used in prior literature because it is more comprehensive as it considers both the environmental and economic advantages (Rizos et al, 2016; Sariatli, 2017; EMF, 2015; Hoogendoorn et al, 2013; Lewandowski, 2016).

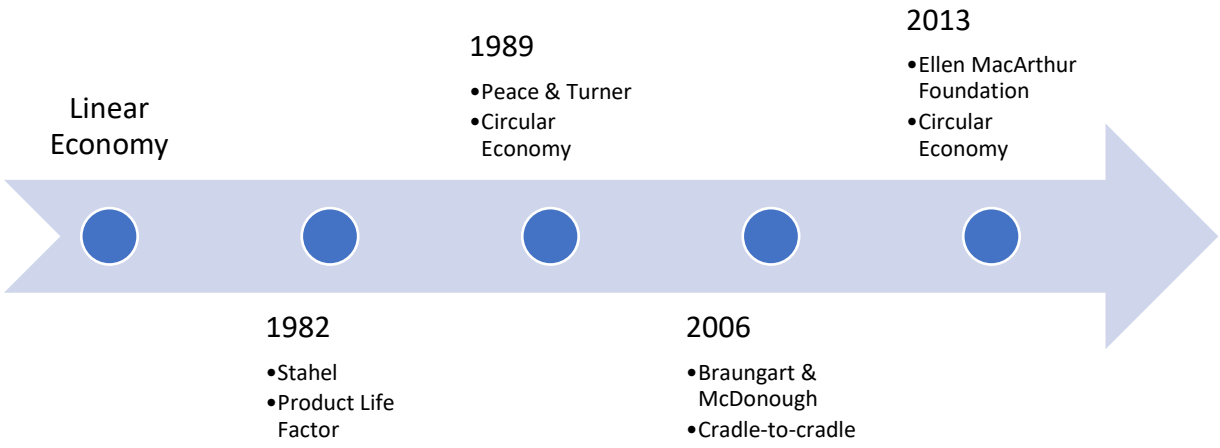

Figure 1: overview theories (source: author)

Barriers and enablers of CE

Prior literature has proven that the implementation of CE has multiple advantages. A change from linear to circular economy models would help avoid emissions, reduce the loss of resources, and ease the burden on global ecosystems (European Environment Agency, 2016). This ecological impact could be a motivation for companies to implement circular economy in order to build a competitive advantage. In recent years there has been a lot of attention for global warming from the demand side, in which companies also play a role. Looking beyond this ecological impact, academics and prior research have recognised the business relevance. The Ellen MacArthur Foundation (2015) found that businesses in Europe could reduce their material cost substantially. An American study found that this reduction could go to USD 700 billion annually in fast-moving consumer goods markets. Besides

cost savings, the implementation of circularity could be an important lever to policymakers to achieve economic growth and job creating (The Ellen MacArthur Foundation, 2015). The latter has been estimated to have an increase to net job creation of approximately 54 000 jobs by 2030, particularly in recycling and remanufacturing, in the United Kingdom (Morgan, Mitchell, 2015). Other research by Bastien et al. (2013) in The Netherlands estimated that more than 50 000 jobs could be created.

Despite the obvious advantages of CE, there are many companies that do not yet apply it because there are some barriers. The study of Rizos, Behrens et al. (2016) did a literature review to find the most important barriers for circular economy. They concluded that Lack of support supply and demand network (54%) and Lack of Capital (50%) were mentioned the most by SME's next to Lack of government support (24%), Administrative Burden (21%) and Lack of knowhow (21%). The lower percentage for Lack of information (12%) might be explained by the fact that companies think the other barriers are more important and that they therefor not yet try to look for the necessary information. Although companies might think that they know the information, it is not always the case and it is surely not the same as being able to collect and produce it, hence the managerial contribution of this master thesis.

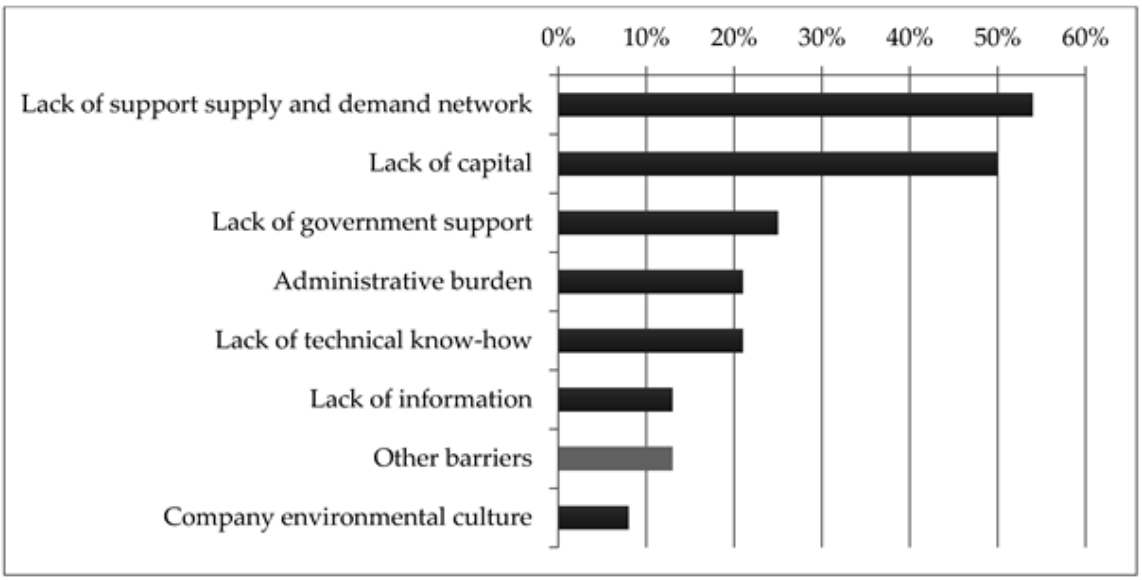

Figure 2: Barriers for implementing CE (Source: Rizos. et al. 2016)

The research of Liu and Bai (2014) found a striking gap between the awareness and actual behaviour of firms. They found that firms have a good image of CE and are willing to implement it but they lack the enthusiasm to do it. Liu and Bai (2014) interviewed 157 firms to find eight barriers mentioned for implementing CE. No incentives are built into the budgetary system that stimulates CE innovation is a structural barrier that Rizos and Behrens (2016) also found. Four out of eight barriers are related to the structure of a company; (1) Employment term limits imposed on managers affect long-term

circular economy strategies, (2) Staff must demonstrate to boss the ways in which new recommendations are consistent with past ways, (3) thereby entrenching a particular path, No incentives are built into the budgetary system that stimulates circular economy innovation, (4) Hierarchical system inhibits flexibility and innovation. Risk aversion of the managers and competing barriers were also indicated to be important, respectively cultural and contextual barriers.
In a survey of Rizos and Behrens (2016) was found that lack of government support was a barrier mentioned by almost 1 out of 4 SME's. In recent years, however, we have noticed an increase in the willingness of governments to also take steps towards a circular economy. For example, we see several working documents at both European and regional level that not only state that they are willing to take steps, but also start telling us how it should be done. This is in contrast to the time period in which Rizos and Behrens's research took place. On the European level, the European Commission established a monitoring framework and reported an action plan for the near future (SWD (2019) 90). This action plan was an extension of the Work Plan 2016-2019 (COM (2016) 773), that already stated the importance of circularity, by means of additional rules for energy labelling and mandating. The European government level of awareness on circularity was also discussed in the work of Tecchio, McAlister, Mathieux, & Ardente (2017). This study stated that the sustainable use of resources underpins the roadmap to a resource efficient Europe and the EU action plan for the circular economy. The European commission provided more than EUR 10 billion to speed up the transition towards a circular economy.
At the Belgian level, we see the same movements taking place, for example, the term circular economy has found its place in the objectives of the 2020 climate plan. The Flemish coalition agreement 2019-2024 no longer only refers to measures, which was still the case between 2016 and 2019 (Samen De Economie Doen Draaien (2016) Peeters, Marghem), but already to concrete figures such as an increase of 7.5 percentage points in the recycling rate (from 70 to 77.5) (Flemish coalition agreement, 2019). The circular economy is also mentioned as an objective in the climate plan 2050 and together with the budgets freed up in the moonshot initiative (EUR 400 million) states that there is an increased importance of circular economy (vlaio.be, 2020). This increase in importance makes clear that the government support no longer needs to be a barrier, but can now rather be catalogued as an enabler.

Business models for CE

In the iterative process of drawing up the model, companies that were considered to be circular were approached. The considered circularity needed to be assessed. A systematic literature review by Rosa, Sassanelli & Terzi (2019) found that there are 3 macro segments in the classification of CBM's: the BMC of Osterwald and Peigneur (2010), the ReSOLVE framework proposed by the Ellen MacArthur Foundation (2015) or thirdly a hybrid model exploitation of the two previous models. The models used in this master thesis are described below.

Components of the CBMC framework

The study of Lewandowski, M. (2016) has worked out a Circular Business Model Canvas. The canvas is an elaboration of the business model canvas of Osterwald and Pigneur (2010). It comprises the first 8 components (value proposition, channels, customer relationships, revenue streams, key resources, key activities, key partnerships, cost structure) and the ninth component (The Need for Additional Components of a Business Model Related to the Circular Economy) is completed by two other components (take-back system and adoption factors) within the study of Lewandowski (2016).

The core component of the circular business model is the value proposition which can be a pure product (eg. LeHigh Technologies turns the rubber of their tyres into other tyres), a product-service system (eg. Philips Pay Per Light) or a pure service system (eg. Virtual Travel). The pure product value propositions propose products that are 100% ready to circulate in the closed material loops. Moreover, product design should allow using less raw material or energy or to minimize emissions. In a product-service system a company offers access to the product but retains its ownership. It is an alternative to the traditional model of "buy and own".

One of the strongest shifts towards a circular business model regarding channels is virtualization, IT and digital innovation is key here. This allows pure services to be offered and ensures that one can reach the customer through more channels. Circular value propositions related to services may concern shifting their traditional form to a virtual one (e.g., virtual travel). Virtualisation can only be made possible if a good information system is involved. An example is digital marketing that will address specific profiles in a targeted manner. Virtually involving or addressing customers is done via data collected in the information system. The information system will have to convert the data in order for virtualisation to succeed. The virtualisation of certain products can only succeed if virtualisation is realistic. In order to achieve this, the tools used must be well attuned to each other; this is a task for information technology.

The different types of value propositions comes with different possible revenue streams. The product-service value propositions comes with input-based pricing streams, like pay per product or pay per service, or availability-based pricing streams, where the customer pays periodically small

amounts of money before the purchase. Other revenue streams are usage-based pricing systems, like pay for use, or performance-based, like performance-contracting.

The different key resources of a company can be classified as physical resources, human resources, intellectual property or financial resources as cash. Two different possibilities occur in the CBMC, one is focused on input choices and the second on regenerating and restoring the natural capital. Circular sourcing is a used way for input choices which applies the principle of using only products or materials obtained from closed material loops. The second circular choice is to use more efficient resources or resources that are from a renewable source. This master thesis addresses the need for data as a resource, which can be seen as a physical resource. The data of a company is a necessary and available tangible item which, when correctly used in the operations of a company, leads to business opportunities.

Each business model is based on some key activities. These key activities ensure that the company in question has more value than its competitor because, for example, it is better able to respond to the needs of its customer. For a circular business model, there are several options for this component. Appropriate product design as a key activity enables using less raw material or energy, to reduce emissions and toxic materials and prolonging the product life according to the cradle-to-cradle concept.

A good partnership brings many benefits to companies: it can reduce risk, close better deals and lead to better key resources. Circularity needs partnerships. A manufacturing company will always have 'waste' somewhere that they cannot convert into by-products, for which a good partner could offer a solution to comply with circularity. The right partner can also ensure that the company itself knows where its resources come from.

The cost structure component describes the most important costs incurred while operating under a particular business model. This component should also be addressed in circular business models. The circular aspect can create extra value for the company, but there will be a cost in return. Finding the right supplier, the cost of sustainable production and installation costs of other (applicable) equipment are among others examples of costs that need to be managed. On the other hand, there are also possibilities to save costs within the CBMC thanks to take-back or recycling of materials or a more efficient way of working. This should also be included in the cost structure.

There are several possibilities to have a circular model. Some models are based on the fact that materials can be recycled after a product has reached the end of its life, with or without preservation of quality. When a company wants to close its cycle, it needs reverse logistics. Reverse logistics is when a consumer brings the products to the producer. For example, H&M will collect clothes from its customers and then later recycle the textiles in the Garment Collecting programme. This component

of the CBMC can give additional advantages to the firm. Thus a new component - the take-back system- can be distinguished in order to differentiate the specificity reverse logistics.
There are two types of adoption factors to go from a linear to a circular business model. On the one hand there are the internal factors such as governance, willingness, knowledge, etc. that can be answered through change management. On the other hand there are also external factors. The most important factors, amongst others, are data management and the use of appropriate technology. Hence, this study is also important in order to know what information/data should be gathered from the information system technology.

Components of the Butterfly diagram

ReSOLVE framework

The Butterfly diagram is an elaboration of the ReSOLVE framework (EMF, 2015). The concept rests on three principles: (1) preserve and enhance natural capital, (2) optimise yields from resources in use, and (3) foster system effectiveness (minimise negative externalities). By carrying out one or several business actions, at least one of these principles will be applied. The ReSOLVE framework states that the principles of the circular economy can be translated into six business actions: Regenerate, Share, Optimise, Loop, Virtualise, and Exchange. Regenerate is about shift towards renewable energy and materials. The share business action are all actions to keep the product loop speed low and maximise utilisation of products by sharing them among users (peer-to-peer sharing of privately owned products or public sharing of a pool of products), reusing them throughout their technical lifetime (second-hand), and prolonging their life through maintenance, repair, and design for durability. The optimise business action is everything to increase performance/efficiency of a product. The loop action states that all components and materials should be kept in a closed loop by means of remanufacturing or recycling for finite materials and chemical processes for renewable materials. Some products can be offered virtually, like music as a file instead of a CD. The last business action, exchange, is about replacing old materials with advanced non-renewable materials.

The butterfly diagram

The butterfly diagram, introduced by the Ellen MacArthur foundation, tries to capture the flow of materials, nutrients, components, and products, whilst adding an element of financial value (EMF, 2017). Influences of the cradle-to-cradle principle of Braungart and McDonough (2008) are visible in the two distinct halves, or cycles, which represent two fundamentally distinct flows of material: biological and technical. The biological material flow are those materials that can safely re-enter the natural world after going through one or more cycles. Those products will return their embedded nutrients to the environment. The technical material flow are materials that cannot re-enter the environment, such as metals and plastics. These materials should hold their value and keep cycling through the system.

In the biological material flow, natural products like water or salt are moving back into the system by processes as anaerobic digestion, extraction, filtering, ect.

Cascades: This loop refers to the process of putting used materials and components into different users and extracting, over time, stored energy and material order. The cascade, for example, might be a pair of cotton jeans being turned into furniture stuffing and then into insulation material before being anaerobically digested so that it may be returned to the soil as nutrients. There are multiple processes to hold the value of the technical materials.

Maintain/Prolong (Share): keeping products and materials in use by prolonging their lifespan for as long as possible through designing for durability as well as maintenance and repair. These longer-lasting products can then be shared amongst users.

Reuse/Redistribute: eBay, Vinted and other marketplaces are proof that it is perfectly possible for some products to be reused multiple times for different owners in one lifecycle.

Refurbish/Remanufacture: When the lifecycle of a product is over, it can be remanufactured. This means that the product will be disassembled to the component level and rebuilt to as-new condition (eg. bikes). Refurbishment is a process whereby a product is repaired as much as possible usually without disassembly and replacement of components (eg. Phones).

Recycle: The process of reducing a product all the way to its basic material level, thereby allowing those materials to be remade into new products. This is undoubtedly an important process in the circular economy.

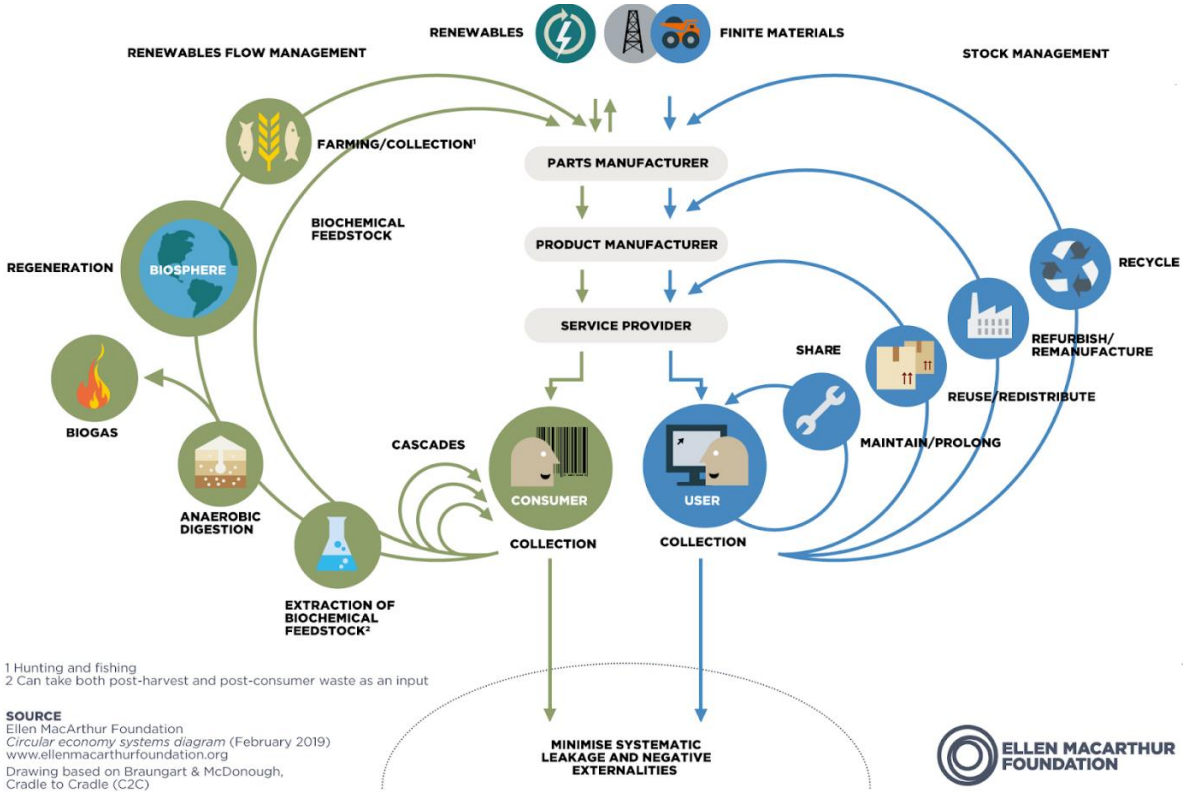

Figure 3: the butterfly diagram (Source: EMF, 2015)

Commonly used business models

There are several types of sustainable business models. Some sustainable business models focus on the development phase, others on the use phase or the after-use phase. Respectively called Circular Innovation Models (CIM), Circular Use Models (CUM) and Circular Output Models (COM) (Ellen MacArthur Foundation, 2016). In CIM, the main focus will be on how products can be produced more efficiently or more sustainably and/or how a longer lifespan can be achieved. In CUM, it is mainly ensured that the product in question is consumed optimally. In COM, revenue is generated through transforming after-use products into new products or useful resources in order to add value, reduce costs, or reduce waste. The development of reverse logistics is essential for this model. If a product is fully designed and produced according to all circular principles but the customer throws it away after use, the outcome is still linear.

There are two ways to bring circularity into the business model. On the one hand, a bunch of independent companies can get involved in a circular chain. By entering into special partnerships, a group of companies can also achieve circularity although the companies itself are not circular. Waste or by-products that would normally be thrown away in one company or have no extra value could be a good input for other companies. This would involve partnerships between companies using either CIM, CUM or COM. On the other hand, there is also the possibility of getting circularity in companies when a company itself is a circular company. In this line of thinking, the same company would then have to comply with both CIM, CUM and COM.

In a circular chain, the success of circularity will depend on good partnerships. For example, a butcher may resell his offal to another company that uses it as input for making animal nutrition. This animal nutrition can then be resold to cattle farms that sell their animals to the butcher.

In a circular company, management will have to think about all components of the business model with circularity in mind. In order to obtain a pure circle as a circular company, it is especially important to thoroughly rethink one's own process. Both the machines to make the product, the materials used, the suppliers, etc. must be of circular origin. There is a need for a certain partnership with the customer to ensure that the product in question returns to the company after use. A circular company will then, once the product has been used and taken back, be able to efficiently recondition and recover the product so that it can be put on the market as new.

Information systems

Introduction

Technological shifts

In the past, many different technological shifts have happened to influence our economy and daily lives. We already went through a couple of industrial revolutions in the past but right now, it is said that we are in another one. The first industrial revolution brought us the mechanisation and steam-machines. It was followed by mass production, electricity and assembly lines (eg. Ford) in the second industrial revolution. The third industrial revolution was about automated production and the use of electronics and IT to do so. In the last years, technology kept on changing on a very fast pace and we are now on the verge where the impact of different technologies is becoming visible all around us. Several new technologies such as 3D printing, data technology, advanced robot processing, etc. have come to the fore in recent years. Scholars and industrialists states that this new stream of technology and its digital transformation of the business world (Ghobakhloo, 2020), referred to as 'Industry 4.0', will have a substantial positive impact on sustainability in the coming years.

Industry 4.0

Today's connected/smart industry solutions allow companies to easily monitor, optimize and improve their production processes. (Industrial) Internet of Things (IIoT) devices such as sensors and connected systems provide decision-makers with new sets of data, shedding new insights on KPIs, primary products, by-products and waste management. By taking advantage of these tools, companies can increase their competitiveness along their entire value chain, ultimately leading to higher profits, all while helping the environment (Source: https://www.eniday.com/en/sparks_en/industry-4-realizes-circular-economy/). The study of Beier et al. (2018) found that an improved transparency provided by the IIoT-enabled digitalization along the supply chain could lead to a better environmental management of companies but only if suppliers are included in the digital networks. The study of Beier et al. (2018) defined IIoT as everything that includes the fusion of the physical world of industrial production with the digital world of information technology – enabling the exchange of live data between machines and product components. This study was done in China but a comparative study of Beier et al. in 2017 found that the Industrial Internet (of Things) is viewed as an important emerging trend both in China and in Germany, those similar results led to conclude that the findings in China are also applicable in the European continent. The rise of Industry 4.0 brings opportunities for organisations to implement circular economy principles into their day to day activities/processes (Ghobakhloo, 2020; Beier et al. 2018).

There is no consensus on how to define industry 4.0. This is one of the main criticisms of

the concept. An extensive literature study by Beier et al. in 2020 studied the different definitions that were in use and tried to fill this knowledge gap. The study itself came up with 3 groups of characteristics of the concept that correspond respectively to the human, technological and organizational concept. They did this because the concept industry 4.0 remains vague and the study noted that the concept is used as a collective term of different developments. The following characteristics were assigned to the specific categories. Humans in an Industry 4.0 setting are expected to do less physical but more mental work, increasingly communicate with partners across the value chain and react to customer preferences. On the technological side, highly efficient automated manufacturing systems will be interconnected building on the standards of the Industrial Internet of Things and a Service-oriented architecture, creating a so-called Industrial Internet of Things and Services.
Organizations in Industry 4.0 need to make use of the above described technological opportunities to become decentralized and flexible, in order to be able to quickly adapt to frequently changing customer requirements. Preconditions for flexibility in organizations are interconnectedness, reconfigurable and modular systems, as well as effective communication between producers and consumers (Beier et al., 2020).

Beier et al. took a survey of the German market in 2017 to examine the sustainability aspects of industry 4.0. They found some interesting results concerning the future of work, the future of production and the perception of saved costs and efficiency. For example, they found that employers in Germany expect that fewer workers will be needed in the assembly and manufacturing sector in the future because of industry 4.0. However, all the other sectors surveyed indicated that they think more jobs will be created. It could therefore be argued that jobs are shifting from the secondary to the tertiary and quartiary sectors. The people questioned in the study of Beier et al. have indicated that they think that more qualifications will be expected from employees in the future. When asked about the future of production, it was found that a higher degree of interconnectivity with both external and internal partners was expected in the future. Companies in China and Germany anticipate that the digitalization of industrial production will influence environmental production factors such as resources and energy consumption.

Opportunities for IS within CE

Business Intelligence

A bibliometrics study (Liang & Liu, 2018) revealed a recent increased interest in BD and BI, it is not coincidental as this could be the result of industry 4.0. Much more data is available because of the interconnectivity that goes with it. The main difference between these 2 cases is that BD is mainly about the technological aspect of data while BI mainly focuses on the decisions that need to be made

by management and information systems (Liang & Liu, 2018). Although these 2 are interlinked because BI is data-driven, BI&A is highly applied and can take advantage of the opportunities offered by the abundance of data and domain specific analysis needed in many critical and impactful application areas. An immense amount of company, industry, product, and customer information can be gathered from the web and organized and visualized through various text and web mining techniques (Chen, Chiang, & Storey, 2012). Applying the circular principles involves a lot of data, the BI of the company must take this into account.

BI&A offers multiple significant advantages for companies. For example, the company can acquire information about the needs and opinions of the customer, which leads to business opportunities (Bozic, 2018). This certainly applies to circular companies. An information system channels the data it acquires into the relevant information needed to make decisions. In this way, an information system also supports the more efficient decision making process, which will also lead to cost savings - a primary reason for some companies to implement CE.

Green IS

Industry 4.0 has given birth, amongst others, to Green Information Technology (GIT) and Green Information Systems (Green IS). Green IT is commonly seen as the technology used to reduce the ecological footprint of companies and individuals and consuming less electricity when changing their processes. To evaluate their ecological footprint, a company should not only look at its data centres but it should look at all domains of their IT services which also have major impacts that can easily be reduced, way beyond their electricity consumption: like water shortage, greenhouse gas emissions and soil pollution (Source: GreenIT Belgium). Other sources state that ecological footprint reductions is only one part of a Green IS. A Green Information Systems is the information system that a company uses to maintain, track and manage their sustainable or circular strategy as a whole (Yang et al, 2017), this broader approach is also used in this master thesis. Green IT aspects concern all technology that is needed to fulfil a green information strategy, like sensors and connected systems (Source: www.eniday.com).

This underlying strategy - referred to as organizational Green IS in the study of Yang et al. (2017) – is how enterprises integrate information system functionalities with production and management activities to achieve their sustainability goals. The Green IS strategy is the combination of the Green IT strategy as well as information strategy, information management strategy and change management strategy. There are three key challenges to achieve a successful IS strategy implementation: (1) to achieve theoretical alignment between strategic intent and system capabilities; (2) to implement the system organizationally and (3) to shape the use of the system and related practices to achieve practical alignment with the strategic intent (Arvidsson, 2014). Those challenges should be tackled to make sure the company does not fail due to strategy blindness. The

study of Beier et al (2017) found that 57.1% of their participants already has an environmental strategy, which makes clear that this is important. An important reason to implement Green IS strategy is cost savings. Cost savings is seen as one of the two main drivers to implement a green information system (Yang et al, 2017). The second main driver next to cost savings is the energy efficiency reason, this was also found in the literature (Beier et al. 2017; Yang, Z et al. 2017; Beier et al. 2018; Ghobakhloo, 2019).

Data as key resource

A systematic literature review of business intelligence system AUS (Ain, Vaia, DeLone, & Waheed, 2019) identified different factors that are critical to BI system AUS. The majority of studies reported either organizational or IS-related factors as being the most important to AUS, whereas user-related measures have received limited attention. This is in line with Fuglseth his study (2005) which said that the strategic advantage depends on the decisions made by the user and not the user itself, so the strategic advantage does not disappear when the user leaves the company. The study of Ain, Vaia, DeLone, & Waheed (2019) found that the most commonly used models of BI system AUS studies were the DeLone and McLean's IS success model and the technology acceptance model.
The DeLone and McLean model (DeLone & McLean, 1992; DeLone & McLean, 2003) suggests that IS success is a multidimensional concept that can be measured through six IS success dimensions, namely information quality, service quality, system quality, system use, user satisfaction and net benefits. The TAM model (Davis, 1989) constitutes two key constructs, namely perceived usefulness (PU) and perceived ease of use (PEOU), which measure individuals' usage behaviour indirectly through behavioural intention. One of the most significant findings in the study of Davis (1989) is the relative strength of the usefulness-usage relationship compared to the ease of use-usage relationship. The quality of information (DeLone & McLean, 1992; Delone & McLean, 2003) indicates the importance of the data used and provided in the information system and thus data as key resource in order to obtain a successful IS which leads to better decisions by its user. The TAM model (Davis, 1989) allows to conclude that an individual is willing to work with a complicated system (lower PEOU) if it gives correct results (high PU). Again, a system, whether or not difficult to handle, will only achieve the right usefulness if the right input (data) is given. The right information will increase both the user satisfaction and the intention to use (Roky & Meriouh, 2015). The case study of Roky & Meriouh (2015) also found a positive relationship between the use and intention to use and the individual impact of an information system. Those findings support the statement for the importance of data and the use of the right information flows within a company. Hence, the importance of this study.
Fuglseth (2005) researched the potential of information systems as a strategic resource and she found that although there are different types of information systems (data-oriented, model-oriented,

and communications-oriented), these in themselves will not create a competitive advantage but they do when they are seen as a complementary strategic resource. A second contribution Fuglseth made was that IS as a resource should be incorporated to a much higher degree in studies.
The Delone and Mclean study describes that the right data is decisive for the success of a BI system. By combining these findings with those of Fuglseth, the BI system is a key source, one can draw the conclusion that data is a key resource for enterprises and their processes and that it will benefit the enterprise if the right information is provided. This master thesis agrees with this and therefore aims to identify the right information flows needed in a circular process.

The supportive role of IS in CE

As mentioned above, the use of BI and Green IS brings many benefits to an enterprise such as business opportunities (Bozic, 2018), cost savings (Bozic, 2018; Yang, Z. et al., 2017), energy efficiency (Yang, Zet al., 2017) and more. The research of Torres, Sidorova, & Jones (2018) links the use of BI&A to improved organizational outcomes through the transformation of business processes, consistent with the view that the value of IT is derived from its impact on the value generating processes of the firm.
Beier et al. took a survey of the German market in 2017 to the sustainability aspects of industry 4.0 and his results were hopeful for sustainability. There has been research on certain sustainable aspects and their relation with information systems. The study of Green et al. (2012), for example, has come to the conclusion that companies benefit a higher organizational performance when implementing a GSCM. The GSCM benefits the operational performance -that leads to the organizational performance- by a leverage in environmental and economic performance. Environmental performance was impacted by cooperation with customers, eco-design and investment recovery. The study of Vugec, Vukšić, Bach, Jaklič, & Štemberger (2020) states that BI is often not aligned with business process management, therefore limiting the increase in organizational performance. By combining the two, the operational performance would be even greater.
We can conclude that the use of BI for a green information system strategy has many advantages for an organization (Bozic, 2018; Yang, Z. et al., 2017; Torres, et al., 2018), if there is a mutual alignment between the business process and the BI (Vugec, et al., 2020). Although no specific studies have been conducted on the supporting relationship of information systems to the circular economy, it can be concluded that this finding also applies to sustainable processes (Beier, et al., 2017; Green, et al., 2012) and thus circular economy. The quality of the information system will depend on the data collected, as described above under data as key. In other words, if the information system knows what information it needs to provide, the BI and ultimately the circular business model will work better. Hence the importance of the purpose of this study.

Design science

Design science research (DSR) is generally accepted as a legitimate approach in IS and as this master thesis focuses on the role of IS in CE this approach was used. As described by Hevner and Gregor (2013) DSR can have multiple knowledge contributions. This master thesis answers to the level 1 knowledge contribution; Situated implementation of artifact, as this master thesis implements the DENICA method, hereafter described, which results in a model of the actors, their role and interconnectivity, present within a circular business environment and the information flows between them. In what follows, the DENICA method is explained and afterwards an explanation is given to the architecture of the solution before going into detail about the solution itself in the artifact description section.

DENICA managerial method

The model itself was made based upon the DENICA-method, which is a method for managers that supports the adaptability of tactical management and its information systems (Petrevska Nechkoska, 2020).

By enhancing the existing roadmap of Sense-and-Respond framework; adjusting some of the components for tactical management needs and by introducing new components and sequences for tactical management use, the DENICA method was constructed and a roadmap was offered. The tactical management method for information systems and managerial adaptability starts with identifying a system of roles and accountabilities, followed by mapping the information sensors, the information emitters and all risks related to the process. The last phase of the DENICA-method is the continuous performance of the Sense-Interpret-Decide-Act loop.

The first phase, identifying roles and accountabilities, is based on the Sense and Respond principles. Here, the importance lies in (1) identifying which roles are important while having in mind the Purpose, the End, and the Reason for Being of the role and (2) how these roles are linked, named accountabilities. All of this is visualised in a Role and Accountability diagram, this can be done by means of SNA. This phase ends with specifying the Conditions of Satisfaction, which can be summarized as: making sure each entity populating the roles has the necessary preconditions to fulfil the expected outcome (Haeckel, 1999).

The information sensors are the information flows that a supervising role should have in order to have an overview of his system, regardless to the current supply of information. This concerns questions like what type of information is needed, type of content, how frequent should the manager get this information, how does the information gets to the manager, ect.

The information emitters are what the manager is told by the other roles in the end in order to be aware in a timely manner of possible issues getting in the way of the agreed outcomes. The

necessary attributes of the Information Emitters are the interested parties in the information flow in question, the emitters of the information and the type of information that needs to be emitted.
The information sensors phase and the information emitters phase are closely related to the risk management part. The risk management phase investigates for each role what the possible risks are that this role cannot fulfil its goal or part of the process. For each role it should be investigated what the risks are concerning the type of risk (experience, lack of knowledge, …), probability of the risk to occur and its impact on the business and how this risk can be approached.
The continuous performance means that this method should frequently be redone in order to continuously have all the right information, emitters and risks.

By performing these steps or phases, the DENICA method tries to help tactical managers to manage a complex adaptive system in a complex, unpredictable and uncertain context. This method was applied in this master thesis because there is still a lot of uncertainty about the circular economy.

Modelling characteristics

In order to find an answer to the existing research gap this master thesis is addressing, the lack of information about the relationship between information systems and the circular economy, the DENICA method was performed. In order to implement this method, the first step was to look for all the roles that belong to or influence the circular process. This quest led to the diagram presented on the following pages. The presented diagram gives a picture of how the different roles within the circular process are influenced by other roles by means of mutual information flows. The arrow, which represents the flow of information between 2 roles within the diagrams also has a certain direction, this is the direction the information has to travel (X → Y: X emits information that Y needs). Information can mainly flow in 1 direction or it can run in both directions (X ↔ Y: X emits information that Y needs while it receives information from Y itself). Who provides information to whom? A single influence was used if one role will mainly and dominantly influence the other.
This master thesis distinguishes between internal and external roles who influences on the company's circular process. This breakdown favours clarity and readability. The external roles diagram represents the actors with which the company as a whole exchanges information and which influence its circular process. The internal roles diagram describes the information flows that are present in the company. Although the internal information flows are the most important for the success of circularity, the green IS will have to accommodate both.
It is important to know that within the diagram of external roles, the actor 'internal' will present the operations of the entire company. The diagram of internal roles is therefore a specification of the external roles diagram. As a result, actors will come back in the internal diagram that were already

present in the external diagram. These diagrams can be seen next to each other but also as a larger package.

Within the internal diagram, the influential factors were divided into 3 groups based on their relative importance. The importance of the different influencing roles in the diagram is illustrated via the relative size of their circle. This importance was found through two units of measurement for centrality within the social network analysis (see attachment 5). A first unit of measurement used was the degree centrality, with a higher score for more influence. This unit of measurement revealed governance firm (8), IT (8) and finance (7) as the most important roles. Followed by CRM (3), marketing (3) and quality organization (3). The shareholders (2) and transport (2) have a rather limited influence. According to this unit of measurement, supplier (1), nature (1), partner in (1), HR (1) and partner out (1) were the least influencing roles. The closeness centrality, where a higher score stands for less influence, formed the second unit of measurement and also identified governance firm (33), IT (31) and finance (33) as the most important influencing roles. Shareholders (49), marketing (48) and quality organizations (42) have less direct influence. Supplier (49), nature (49), partner in (49), CRM (48), transport (51) and HR (51) had the rather limited influence here. Relatively speaking, partner out (63) has almost no influence. In the diagram, the roles served as the actors or nodes and the information flows between them served as links, also referred to as arcs or edges (Otte & Rousseau, 2002, p443). When the two measures and their results are combined, it could be stated that there are 3 levels of influence observable: high influence (IT, Governance, Finance), medium influence (Quality organism, Shareholder, Marketing, CRM) and low influence (Transport, Partner in, Nature, Supplier, Partner out, HR).

The different roles were allocated in levels based on how closely they are involved in the process. This allocation was made because it became clear during the interviews that information from different levels required another approach in order to obtain the information. This allocation was made in the first phase of the DENICA method. This led to the four following levels: circular enterprise, enterprise, business ecosystem, world. The actors were allocated to the circular enterprise-level if this actor is directly active in the circular process of the enterprise itself. The enterprise-level consists of all actors who have a direct impact on the circular part of the enterprise without being part of it. Actors in the business ecosystem are actors who are having an direct impact on the circular process of the company. The world-level is the combination of actors who have an indirect impact on the enterprise processes.

Artefact description

A system of roles and accountabilities

A system of roles and accountabilities across the broad business ecosystem

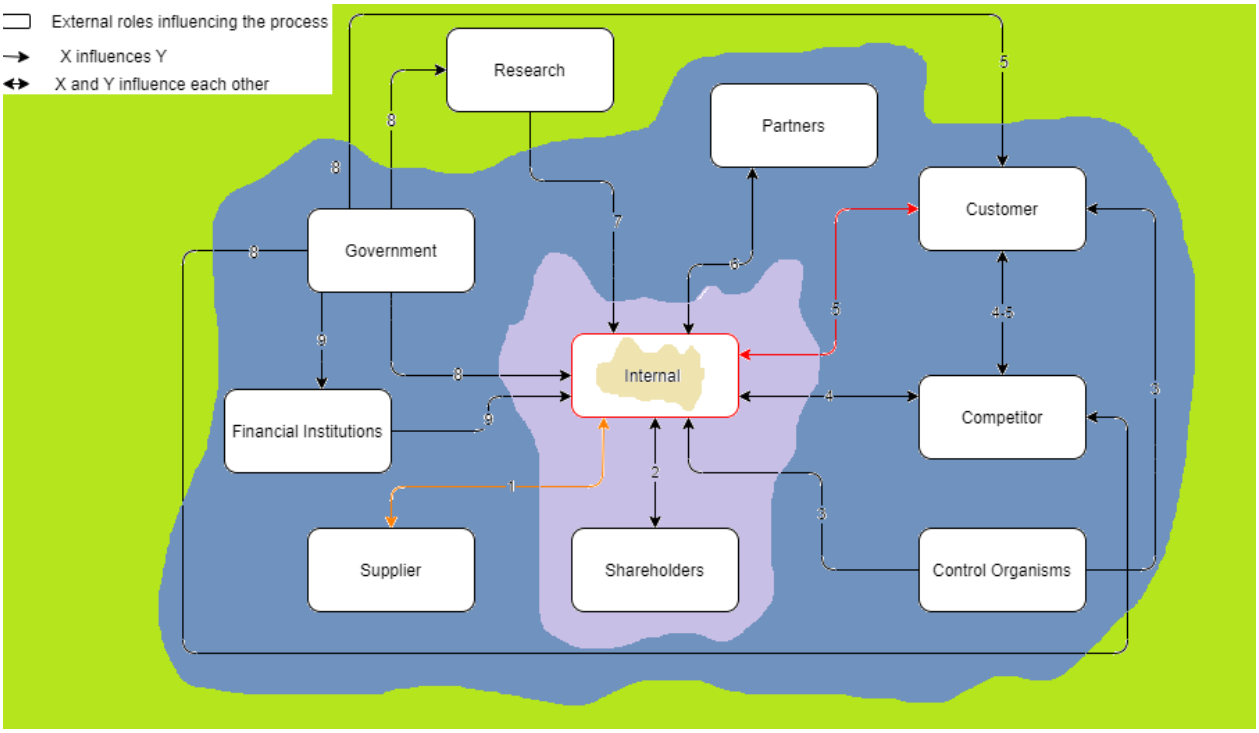

Figure 4: Visualisation of roles and accountabilities across the broad business ecosystem (Source: author)

The different roles (internal organization (internal), partners, customers, competitors, control organisms, shareholders, suppliers, financial institutions, government, research) that are present within the diagram were identified through an iterative method in which own findings, knowledge from literature and interviews were addressed (see attachment 6).

1. The relationship between the organisation and the suppliers goes in two directions. On the one hand, the organisation depends on the information provided by the supplier in order to make a good judgement of which suppliers it will work with. Prior literature (Rizos, Behrens et al., 2016) found that lack of support from the supply chain was one of the most important barriers for companies. It can happen that the supplier will make circular or sustainable proposals. On the other hand, the company will be able to influence the supplier if it will present specific sustainable or circular requirements. The latter was described in prior literature (EMF, 2016) as CIM. A product can be developed more sustainable if the used inputs are from a sustainable source.
2. The shareholders of the company and its governance should have the same mindset. There are many advantages of CE for a company, but this is more in the long term, which is why the governance will have to convince the shareholders to implement CE aspects and vice versa. The governance of the company will not be able to apply circular economics if the

shareholders do not allow it and on the other hand shareholders will not be able to apply circular economics if the governance does not want to implement it. In prior literature, the study of Liu and Bai (2014) found that many companies want to adapt circular principles but that they did not do it mostly because of structural barriers which is led by decisions from the shareholders and day-to-day governance of the firm.

3. External control organisms can influence the organisation. If an external control organism detects a certain irregularity, this can jeopardize the credibility of the company and the company will have to intervene. This control organism can be appointed by the company itself or they might be independent partners. This can be important, for example, to prevent greenwashing. The report or conclusions, and accompanying certificates, of an external control organism can have an influence on the customer.
4. The company's competition obviously has an impact on the company's circularity. If a company establishes that a circular competitor is doing well, it can decide to implement this itself. On the other hand, a company may decide to implement CE itself first in order to obtain a competitive first mover advantage. It is not convenient to obtain this information about the competitor's processes as the competitor will usually not just reveal it. The company has to find an indirect way to do so, eg. through sustainability reports.
5. The customer of a circular company obtains many influences from different actors. The most important input that the customer of the circular company experiences are the awareness campaigns of the government. Once the customer is aware that circularity is an important aspect to maintain the current standard of living, it will adapt its personal needs accordingly. The EMF (2016) described CUM as models where it is mainly ensured that the product in question is consumed optimally. The behaviour of the company and its competitors (4) in the market will influence the customer. Prior literature (Rizos, Behrens et al., 2016) found that lack of support from the supply chain and demand network was one of the most important barriers for companies. The customer can also influence the governance of the company based on specific questions.
6. Every company has the opportunity to enter into partnerships with other companies in the company's ecosystem in order to keep any by-products, or waste that it cannot recycle itself, in a circular chain (Lewandowski, 2016). Products or materials that the company took back from its customer, but is unable to recycle, can serve as cascades in another product (EMF, 2017). On the other hand, the company itself has the option of buying certain raw materials from other companies to process them in its own production. When companies are not able to pursue the circularity of their own company, they can ensure circularity through means of forming a circular chain with partners.

7. Universities and research centres are looking for new innovative technologies on a daily basis. These new technologies and inventions can have an indirect impact on the enterprise if these technologies can be used by the enterprise to improve their circular process.
8. The role of the government is very important in the circular aspect and was also stated by SMEs in the study of Rizos, Behrens et al. (2016) as an important barrier. Regulations will have a direct impact on the company and its competitors. On the other hand, the government will also be responsible for subsidising research into new technologies (7), starting up and supervising new circular initiatives and more. The government's certificates (European Commission, 2016) and awareness-raising campaigns (5) are more likely to have an indirect impact on the company as they are more focused to have a direct impact on the consumer. The government has cultivated a certain interest in the circular economy and is now setting itself concrete goals it wants to achieve in the future along with measures to achieve them. In the literature review, this trend was found at the European (European Commision (2016), European Commission (2019)), national (Peeters, Marghem (2016) and regional (Vlaams Regeerakkoord, 2019) levels.
9. It is very feasible that the company needs to go to a financial institution in order to obtain its needed finances. The financial institution will then analyse the company and make a decision whether they are going to lend the money or not, this has an impact on the decision that the company will make about investing in new technologies like green IS. The study of Rizos, Behrens et al. (2016) found that a lack of capital was a barrier for many companies. The financial institutions themselves will have restrictions put on by the government.

System of roles and accountabilities across the business ecosystem, decomposed with internal roles

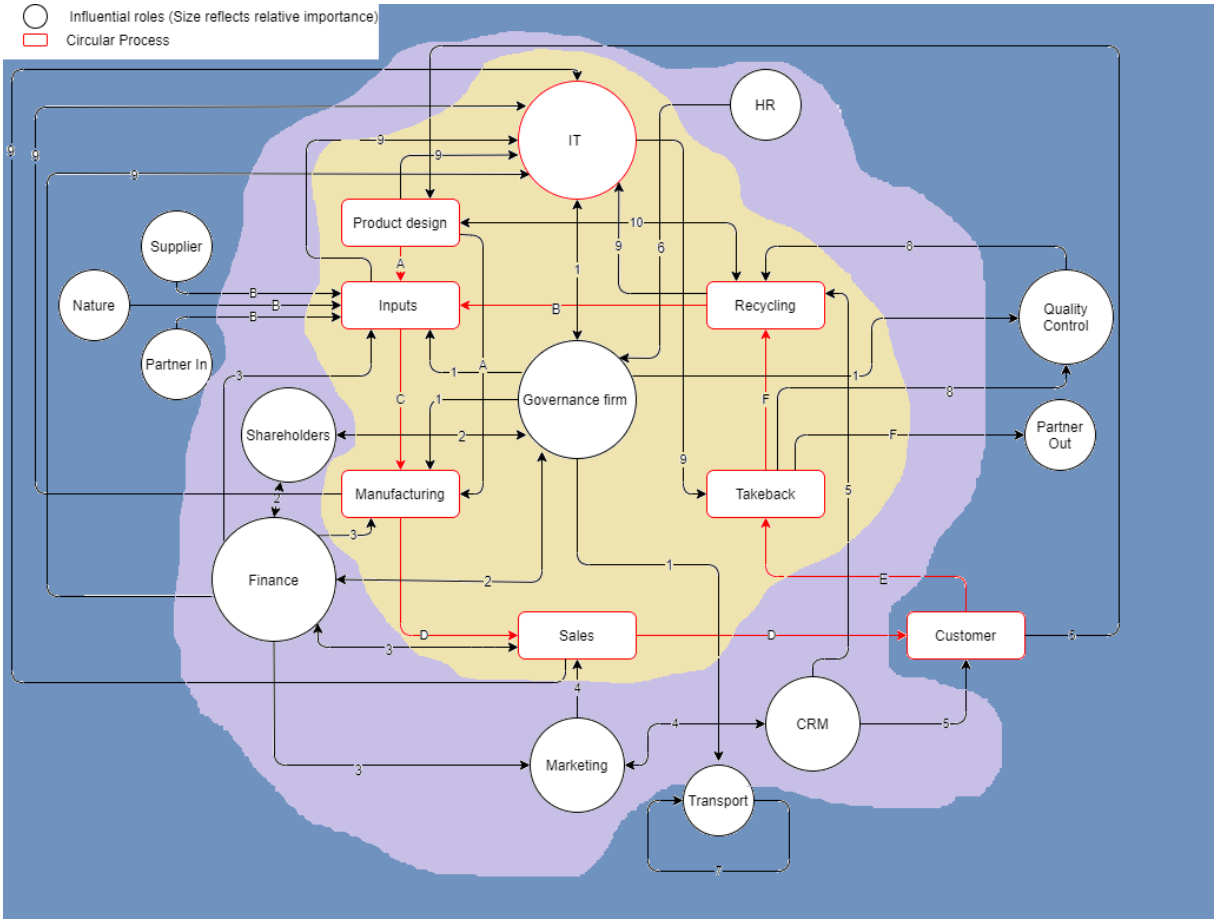

Figure 5: Visualisation of roles and accountabilities across the business ecosystem, decomposed with internal roles (Source: author)

The different roles (HR, Quality control, IT, Partner, Customer, Takeback, CRM, Transport, Marketing, Sales, Finance, Manufacturing, Shareholders, Governance firm, Inputs, Product Design, Recycling) that are present within the diagram were identified through an iterative method in which own findings, knowledge from literature and interviews were addressed. The interrelationships were also drawn up using this iterative method (see attachment 6).

Circular process

To obtain a circular product, the product must first have a circular design (A). The CBMC from Lewandowski (2016) stated that a circular company could gain a competitive advantage if it used the product design as its key activity (Osterwald and Peigneur, 2010). Even before the circular process can start, the design of this product needs to be considered so that it can be brought into a circular process in the future, CIM are primarily discussing this topic (EMF, 2016). The production design determines in the first phase of the circular process which inputs the process needs, how the product will be produced in manufacturing, when it should be taken back in order to be able to recycle it later on. There are multiple sources of inputs available for a circular process (B). In a circular company the input of a circular process can come from another producer from the circular chain (partner), from

nature, purchased from a supplier or the recycled materials from its own circular process (recycling). Circular sourcing (Lewandowski, 2016) is a way to choose inputs which applies the principle of using only products or materials obtained from closed material loops. The collected inputs will come together in the manufacturing department (C) and will be processed into a finished product that can be sold (D) to the customer. The customer (E) will start using the product in a way that this is optimally used (EMF, 2016) and when it is consumed after a certain amount of time it will have to be taken back by the company. The customer should try to keep the product as operational as possible, for as long as possible in one loop by sharing, maintaining or reusing it (EMF, 2017). The take-back system of the company (F) was described as reverse logistics (Lewandowski, 2016) and in studies about COM (EMF, 2016). The company will check the products taken back and, if possible, recycle them. After recycling, this recycled product serves as input (B) which then fulfils the idea of circular sourcing (Lewandowski, 2016) in a circular company. For those products that the company cannot recycle itself, it will be able to enter into a partnership with a partner within the company's ecosystem because the product can still be kept in a circular chain. Partnerships are a must for most companies to achieve circularity and are therefore also included in the CBMC (Lewandowski, 2016). Those partnerships make sure that a company that is not circular in its essence can still be in a circular chain or that a circular company can lever its circularity.

Internal influences on the circular process

1. The company's governance will determine what type of inputs the company uses, how the production process is carried out and what quality requirements are imposed. The governance of the company should be aware of circularity and needs to be willing to implement it. The study of Liu and Bai (2014) found that companies are aware of the concept and are willing to implement it but they do not do it because they lack the knowledge to do so. The latter is described as the internal adoption factors in the CBMC framework of Lewandowski (2016). The company's governance will also determine the extent to which reporting will eventually take place, as IT is able to do this automatically. The governance of the company will also decide by whom (internal or external) and how the transport will be carried out.
2. The shareholders of the company and its governance should have the same mindset. There are many advantages of CE for a company, but this is more in the long term, which is why the governance will have to convince the shareholders to implement CE aspects and vice versa. The governance of the company will not be able to apply circular economics if the shareholders do not allow it and on the other hand shareholders will not be able to apply circular economics if the governance does not want to implement it.

The shareholders will impose certain financial objectives upon the company, it will be the task of the governance to achieve these objectives. The policy decisions of the governance depend on the financial figures and the figures depend on their policy. The objectives that are set should be set with the value proposition in mind (Osterwald and Peigneur, 2010).

3. In addition to the imposed objectives of governance and shareholders (2), the financial part of a company will also monitor other aspects. The collected inputs have a certain cost which has to fit within the budget of the company, in order to control this, both have to be included in the IS (9). Rizos, Behrens et al (2016) also found that the financial situation of the company was a great barrier to implement CE-principles. Liu and Bai (2014) came to the same conclusion in their study. The same budget will impose restrictions on the marketing department and set targets for the sales department. On the other hand, the financial department also depends on the expectations of the sales department. A circular process should also take into account the processing of all inputs in manufacturing as efficiently as possible. Prior literature also stated that the cost aspect is a very important part of every business (Osterwald and Peigneur, 2010) but that cost savings, by not having to buy the product as new, should also be taken into account (Lewandowski, 2016).
4. The efforts of a company's marketing department will have an impact on that company's sales. Marketing itself will depend on both the obtained budget from finance (3) and the CRM of the company. CRM and marketing will have to be aligned with each other.
5. The extent to which the company succeeds in practicing a good CRM has an influence on the customer's behaviour. It is the CRM his task to link the customer to the company in such a way that after the use or consumption of the product it will return it to the company (E). In a customer centric organization, the customer also influences the product design. The product design must be susceptible to be put on the market or to find out which products the customer wants. These surveys are then conducted by either the product design department or the marketing department. If the company succeeds in getting the customer to participate in the circular story, the customer will possibly use the product in a more sustainable way. This results in a higher degree of recyclability of the product and thus a better circular process. CE brings opportunities to link the customer more closely to the company and thus to build a more sustainable relationship with the customer.
6. It is important for a company that its mission and vision is shared by its employees. If the employee believes in the sustainable and circular aspect of the company, he or she will personally try to contribute to this. The role of governance is to attract the right people.

Although the opposite relationship is also possible, it is sometimes possible that certain employees can use intrapreneurship or personal conviction to establish certain processes or ways of thinking in the governance of the company.

7. The way in which the company transports has an influence throughout the entire circular process of the company. A partner within the company's ecosystem can be called upon for this, but it can also be carried out by the company itself. This is why the transport actor lies on the boundary between the enterprise level and the ecosystem. The actor transport deals with the transport of the obtained inputs, the transport from factory to customer, the way in which the returned product arrives at the recycling centres (Lewandowski, 2016) and how it subsequently returns to manufacturing. The company's governance has to make decisions about means of transport, executing party, location of departments, etc. influencing this role.
8. The quality control for product take-back is based on standards imposed by governance (1). Quality control must be applied to the products coming from the customer so that the recycling process is not disrupted in the following step. After the recycling process, it will then be checked whether the recycled products are of sufficient quality to be used as input for a new process (B).
9. As stated in the background section, the company's information technology plays a crucial role in the circular process (Vugec et al., 2020). In order to be able to carry out a correct and good circularity and to guarantee the follow-up of this, it is important that the information system will collect the correct information from the different actors involved in this process (Chen et al., 2012). Decisions can then be taken easier and quicker in order to achieve business opportunities (Bozic, 2018; Roky & Meriouh, 2015). The IS plays a central role. As described in the next section, it collects information from different roles (Input, manufacturing, sales, customer, take-back, recycling, product design, finance, governance) and converts it into information that other departments need as input or that the company can report.
10. In the initial product design, the product will be designed so that it can eventually be recycled as completely as possible. However, it can happen that new technologies create new opportunities or that the effective recycling does not run as expected and then the product design can be adjusted.

Information sensors, emitters and information flow specific risks

The aforementioned model gives a general overview of the circular process and the influencing roles both across the broad business ecosystem and decomposed with internal roles. This model was drawn up based on literature, own findings and the interviews. Because all these issues were

intended to describe the role of information systems in the circular economy; information sensors, information emitters and risks will only be described by looking at the roles that are directly involved with the subject and their interconnected information flows.
In what follows, all roles of the circular process together with the IT role are described, according to the DENICA method, because those roles are the ones investigated and specified in this master thesis. This immediately gives directions for further research as the other information flows and roles are no further discussed. For each role an explanation is given about the incoming information flows; which information flow is discussed (the information sensors), how they should be delivered (information emitters) and what possible risks are associated with this. To clarify, it is only about the incoming information flow, so a relationship can occur twice if that relationship runs in 2 directions (information flow i. is discussed at point A if it runs between a and A in the direction of a to A). This will result in a non-exhaustive list of information flows that can form the basis for a green IS when implementing a circular economy.

A. Product design
    a. Customer (5)
        i. Sensors: In a customer centric organization, the customer also influences the product design. The product design must be susceptible to be put on the market or to find out which products the market/customer wants.
        ii. Emitters: The design department or marketing department can do this through surveys, interviews, questionnaires, 'follow-me-home' research, mapping customer process, diary studies, … This should be done at least once for each product.
        iii. Risks: (1) The customer is not reachable, gives incorrect information or does not know what he wants. There can be a difference between what the customer says and what he actually wants. (2) Misjudgement of interviewer, researcher. (3) Changing needs over time.
    b. Recycling (10)
        i. Sensors: The recycling department has certain specifications, it cannot recycle everything because it depends on the facilities present. The product design will design the product in such a way that it can be recycled at a later stage, so it has to take into account what the recycling department can recycle.
        ii. Emitters: Qualifications of the machines present and their capacities. Information should be exchanged every time something changes in the qualifications.

iii. Risks: (1) Machinery may break down, be replaced or, due to circumstances, (2) the machinery may not be able to meet its intended capacity.

B. Inputs

a. Product design (A)

i. Sensors: The production design determines in the first phase of the circular process which inputs the process needs in order to be recycled later on.

ii. Emitters: The product design can made in specific CAD software (eg. AutoCAD, SolidWorks, tinkerCAD …). The product design in combination with the production process will process the needed inputs.

iii. Risks: (1) The product design is not correctly transferred or has not thought about the availability of inputs that needs to be used. (2) A mistake was made in the design, resulting in wrong measurements of the CAD. (3) the CAD methods are incorrect.

b. Supplier – Partner In – Nature (B)

i. Sensors: How were they produced? Where did they come from? How durable are they built? Characteristics of the supply chain, inputs?

ii. Emitters: Brochures, quotes, websites of suppliers, … How often this data needs to be adjusted depends on how often the suppliers change; weekly, monthly, annually, etc.

iii. Risks: (1) lack of knowledge about inputs as the suppliers don't want to give transparency in their process. (2) Information is not sufficiently frequent adjusted meaning old values are used.

c. Finance (3)

i. Sensors: The collected inputs have a certain cost which has to fit within the budget of the company, in order to control this this information on the budget should be gathered.

ii. Emitters: the FP&A of companies in specific programs (eg. Adaptive Insights) or overall programs (eg. SAP), the budgeting of the finance department. This should be communicated annually for reporting standards.

iii. Risks: (1) With the budget set by the finance department, it is not possible to finance the requested inputs from the product design. (2) The budget is communicated too late or incomplete. (3) Big chances in the year influencing the FP&A

d. Governance firm (1)

i. Sensors: The governance of the company will put standards for the requested inputs or used suppliers.
ii. Emitters: Standards put by governance.
iii. Risks: The lack of knowledge about the possible suppliers or ways of input.

e. Recycling (B)
i. Sensors: The recycled products can be an input in the new processes. This is why the recycling department has to make predictions about the quantities of each type of product being recycled.
ii. Emitters: Projected numbers of the recycling department, monthly communicated.
iii. Risks: (1) The projected numbers are not met due to malfunctioning of machinery, (2) bad conditions of reversed products or used inputs, …

C. Manufacturing
a. Product design (A)
i. Sensors: The product design department will partly determine how the product is manufactured. It will determine which order the production process will have to maintain.
ii. Emitters: The blueprints of the production process generated in the CAD-software.
iii. Risks: (1) The product design did not sufficiently document the production process. The layout of the factory does not allow this production process. (2) the manufacturing departments IS is not able to open CAD-files.

b. Inputs (C)
i. Sensors: The collected and stored inputs must be forwarded to manufacturing. In this way the production knows which stock it still has of which product.
ii. Emitters: Inventory of products, this should be continuously monitored in real-time. Software as SAP Business One or Oracle can be used.
iii. Risks: (1) The risk is that the inventory runs out or that the inputs have wrong characteristics. (2) lag on information

c. Governance firm (1)
i. Sensors: A circular process should take into account the processing of all inputs in manufacturing as efficiently as possible. The input will be restricted by the budgeting of the finance department.

ii. Emitters: The FP&A of companies in specific programs (eg. Adaptive Insights) or overall programs (eg. SAP), the budgeting of the finance department. This should be communicated annually for reporting standards.
iii. Risks: With the budget set by the finance department, it is not possible to finance the requested production process. The budget is communicated too late or incomplete.

D. Sales
    a. Manufacturing (D)
        i. Sensors: The collected and stored finished products and products under construction must be forwarded to sales. In this way the sales department knows which stock it still has and how far the process of the other products has evolved.
        ii. Emitters: Inventory of manufacturing can continuously be held through ERP-systems like SAP Sales or Acumatica.
        iii. Risks: (1) The risk is that the inventory runs out or that the finished products have wrong characteristics. (2) lag on information (3) no unilateral use of codes ect.
    b. Finance (3)
        i. Sensors: The financial department draws up its budgets based on forecasts that the sales department will make. The financial department itself will also impose targets on the sales department in order to support the budgeting.
        ii. Emitters: The FP&A of companies in specific programs (eg. Adaptive Insights) or overall programs (eg. SAP), the budgeting of the finance department. This should be communicated annually for reporting standards. Targets set for the sales department, found in software programs as Salesforce, Teamleader, PowerBI, ect.
        iii. Risks: Exceptional circumstances that endanger sales: e.g. shutdown of sales processes, company damage or staff shortages
    c. Marketing (4)
        i. Sensors: The effectiveness of the marketing department will influence the sales process. They also impose certain things such as the target audience and make the sales department's work easier through their marketing actions.

ii. Emitters: The marketing actions of the company through the different marketing channels. Those can be updated and analysed in CRM-software or Google Analytics.
iii. Risks: (1) The desired effect of the actions is not achieved. (2) The IS cannot upload the information.

E. Customer
   a. Sales (D)
      i. Sensors: When the sales department accompanies the customer in the purchase process, it will already have to point out the circular aspect of the product and how the process does not stop at the customer.
      ii. Emitters: Sales talk in the purchase process. Software like Salesforce Teamleader or SAP Sales can provide useful information on the customer's leads. This should be real-time information.
      iii. Risks: (1) The sales department is too sales driven so the message does not get across clearly. The customer is not interested in a circular product. (2) Information on leads is not correct.
   b. CRM (5)
      i. Sensors: During the customer's consumption process, the company will need to have sufficient customer contact points to provide the customer with an incentive to return the product.
      ii. Emitters: E-mail messaging, social media, chat rooms, CRM-software…
      iii. Risks: The contact details about the client are not kept, weak management.

F. Takeback
   a. Customer (E)
      i. Sensors: Information must be collected from the products that the customer would like to return to the company. The take-back department then has to decide which items to take back or not.
      ii. Emitters: Platform on company's website where the customer can ask for a takeback, mails send from customer to company. This can be done through contact forms on the company's website, contact details, …
      iii. Risks: (1) The customer is not aware that he can bring back the used product, the customer does not know how to do it, the customer doesn't want to. (2) The communication with the client takes too long.
   b. IT (9)

i. Sensors: The designers will know after how much time the product is approximately consumed. If the information system will keep track per product how long it has been used by the customer, it can help the take-back actor to retrieve the correct products in time.
ii. Emitters: Lists based on sold products, sell date and the approximated product consumer phase time. Those lists should be sent out monthly and gathered by the general ERP or BI system of the company.
iii. Risks: (1) The IS is not able to collect this much information, (2) if the usage phase lasts for too long the data can expire or can be overwritten due to mistakes.

G. Recycling
   a. Takeback (F)
      i. Sensors: The characteristics of the products taken back must be forwarded to the recycling department. This forms the foundation for the recycling of the goods.
      ii. Emitters: Characteristics of products listed in takeback department.
      iii. Risks: (1) The characterisation did not go well causing the wrong processes to be applied. (2) Characterisation or product control has not (yet) taken place, so this still needs to be done in this department.
   b. CRM (5)
      i. Sensors: If the company succeeds in getting the customer to participate in the circular story, the customer will possibly use the product in a more sustainable way. This results in a higher degree of recyclability of the product and thus a better circular process.
      ii. Emitters: Degree of recyclability of products taken back as measure. Information can be updated and analysed in CRM-software or tools like Google Analytics.
      iii. Risks: (1) Information is not kept up to date. (2) The customer is not reachable.
   c. Quality control (8)
      i. Sensors: Product control will influence which products can be recycled. These returned products will have to be compared with some standards in order to evaluate them.
      ii. Emitters: The standards used for quality control and list of approved and controlled companies. These should be communicated after every change.

iii. Risks: (1) The products taken back do not meet the quality control requirements, as a result of which too few products are approved. (2) The quality control does not take place sufficiently well so that the recycling department is left with pieces it cannot recycle.

d. Product design (10)

i. Sensors: The recycling department will have to recycle the product designed in the product design department. This ensures that the decisions made in the product design department will influence the recycling department.

ii. Emitters: Blueprints of product design retrieved from the CAD software with recommendations for the recycling process.

iii. Risks: (1) The customer abuses the product so that it can no longer fulfil its goals put by the product design. (2) The CAD files cannot be red by the IS of the recycling department.

H. Information technology

a. Governance firm (1)

i. Sensors: The company's governance will also determine the extent to which reporting will eventually take place, as IT is able to do this automatically.

ii. Emitters: The system requirements imposed by the management, chosen standards, chosen reporting, … This should be communicated on a yearly basis to make sure all the right data will be collected.

iii. Risks: (1) Lag in communication, resulting in not keeping track of the right data. (2) Communication is not clear.

b. Recycling (9)

i. Sensors: The IS needs to keep track of the productivity of the recycling department.

ii. Emitters: Inputs received from take-back, outputs for recycling department that can be used as input for the circular process, capacity of recycling process, … All those aspects can be judged on monthly basis through a BI or ERP tool.

iii. Risks: (1) The data sent from recycling department is not representative as the recycling department doesn’t keep track or doesn’t know how. (2) The data is badly presented in the BI or ERP tool.

c. Sales (9)

i. Sensors: The sales department must pass on information to the IS of the products sold. Through this information, it will be possible for the IS to point

out which product at which customer is ready to be taken back or recycled after the usage phase of the product.

ii. Emitters: Lists based on type of product sold, sell date, customer name, … Those lists should be sent out monthly and gathered by the general ERP or BI system of the company, eg. SAP Sales or Acumatica.

iii. Risks: Information gets lost or there are changes in usage time, customer contact information, … that isn't reflected or up to date in the information.

d. Manufacturing (9)

i. Sensors: The manufacturing department must pass on information to the IS so that it knows how much inventory, stocks, products in manufacturing, used inputs, …

ii. Emitters: Lists based on type of product, assembly line, used inputs, received outputs, … Those lists should be sent out monthly and gathered by the general ERP or BI system of the company.

iii. Risks: Information gets lost or there are changes in the manufacturing process which aren't reflected in the information.

e. Inputs (9)

i. Sensors: The input department must pass on information to the IS so that it knows how much inputs are collected from which type of input for which product.

ii. Emitters: Lists based on general ledger, invoices, used inputs, received outputs, … Those lists should be sent out monthly and gathered by the general ERP or BI system of the company.

iii. Risks: Information gets lost or data is badly presented in the BI or ERP tool.

f. Product design (9)

i. Sensors: The inputs estimated to produce the product, the amount of employers working on it, … Those estimates and forecasts can later on be compared to the real numbers for management purposes.

ii. Emitters: The blueprints of the production process generated in the CAD-software.

iii. Risks: (1) There is a lack of knowledge on estimating all those aspects which results in not doing it. (2) The IS is not able to open CAD files.

g. Finance (9)

i. Sensors: The financial department will provide a budget for all departments based on estimates. The information system has to collect, amongst other

things, the information in order to be able to verify these estimates with the actual values at the end.

ii. Emitters: Budgeting of financial department, general ledger, asset management, annual closing, … . The actual values in the end of all different departments. Financial ratios. Those values are collected in the ERP tool SAP Finance or other tools like Adaptive Insights.

iii. Risks: (1) The different departments are not collecting the necessary information. (2) Different departments are working with different numbers. (3) Lack of knowledge on how to produce the information.

Risks

Every company should try to investigate the risks in its own process. Next to the specific risks mentioned in the section above, every company has its own company-specific risks. The biggest risks lies in the lack of knowledge, malfunctioning of the information system, lack of communication, …

Continuous performance of the SIDA loop

The fifth phase of the DENICA model states that there should be continuous performance of the SIDA loop. The Sense-Interpret-Decide-Act loop is an iterative loop starting at *sensing* changes in the environment and/or internal states. These changes will be *interpret* in the context of their experience, aims, and capabilities, separating threats from opportunities and discarding irrelevant information. These interpretations will result in *decisions* on how to address the sensed change. The phase of interpretation is the main means of distinguishing whether the information signals captured from the inner and outer environment are relevant for our system's behaviour and achievement of purpose—after which the decision is made if and how to *act* in response. The progression from sensing to interpretation to decision to action becomes an iterative loop as the adaptive system monitors the results of its previous actions and picks up environmental changes that have occurred since the previous cycle. (Petrevska Nechkoska, 2020).

The continuous performance means that this method should frequently be redone in order to continuously have all the right information on the system diagram, sensors and emitters and risks. This means that a company should rethink its own process whenever there happens to be a change in one of the roles of the company's business ecosystem.

Discussion

During the study the role of IS in the CE was examined. Some findings became clear:

- Literature on this topic is insufficient
- The information flows and the influencing roles within the CE are not only located in the circular part of a company but extend to the entire company and its business ecosystem
- The IS itself must process information based on inputs received from other departments while it needs to distribute information between the active roles of the circular process.
- Insights in the circular process described below

Central role of IT

It is the primary goal of the predecessors to deliver a product to the company that meets the requirements imposed by the company. With these inputs the company can then start to make a circular product based on the needs of the customer. This master thesis examines the role of the IS to do the latter. The role of the green IS is to support, collect and convert the information flows of a circular process. Although the internal information flows are the most important, the green IS will have to accommodate both the internal information flows and the exchange of information with external actors. When the IS of a company has a supporting role in the circularity, thus becoming green IS, it allows companies to reduce the barrier to CE by not only knowing what information they need, but also letting them produce it. Literature on this topic is insufficient as the first model, drawn up based on the literature, needed many additions. Hence the need to modify the model several more times by reviewing and incorporating both theory and practice.

A first finding in this master thesis is that, by elaborating the DENICA method, we see in the diagrams that the information flows and the influencing roles within the circular economy are not only located in the circular part of a company but extend to the entire company and its business ecosystem. The business ecosystem in this master thesis was defined as actors who are having an direct impact on the circular process of the company without necessarily being part of the company.

The diagram of the circular process was drawn and the most influential roles of the internal diagram were found through SNA measures. For the internal roles, it was found that the governance, finance and IT of the firm are the most influential roles.

Non-exhaustive list of information flows in the circular process

The main finding of this master thesis gives contributions to both managers and researchers. After completing the DENICA method, the information flows between the roles of the circular process and the information systems were listed, as found in the table below. A description of the found information flows is written in what follows.

The product design department will make its design based on (1) the requirements and expectations obtained from the customer, (2) the specifications of the processes and machines used in the recycling department and (3) which inputs are available to the company. These incoming information flows will provide the information system so that this department can design the product. This leads to the design of a certain blueprint of this product and its process that needs to be forwarded, outgoing information flow, to the input department, recycling department and manufacturing department.

The input department will have to keep track of the various possible sources of input based on brochures obtained, quotations and the like. The input department will have to compare these data with the requirements imposed by the company's policy and the budget imposed by the financial department. They will have to do this taking into account the input requirements they have received from the product design. After the input department has done its work, the actual costs, collaborations and inventory will have to be sent to the information system so it can compare the actual results with the budgeted figures.

The manufacturing department must carry out a production process based on the received product design, taking into account the working conditions imposed by the company's policy and the number and type of inputs obtained from the input department. The manufacturing department will be encouraged to do this as efficiently as possible in order to stay within budget and not to waste anything unnecessarily. When a product is finished, this department will have to forward the actual costs, input used, finished products and so on to the information system so that it can make a comparison between the actual and planned data. Furthermore, the manufacturing department of a produce-to-stock schema will also have to communicate with the sales department so that they know how many products of each type can be sold. The sales department will have to try to sell the finished products to the customer. In a produce-to-order schema the roles of the sales and marketing department should be switched in the presented artifact. This type of schema, a production method in which a product is made by the manufacturing department only after it has been ordered through the sales department, offers more potential for circularity and sustainability as it could reduce stock levels, hence avoid possible loss of products.

The sales department will have to try to sell the finished products to the customer. It is important that the sales department, together with marketing, communicates the circular idea of the product to the customer in a convincing way. The sales department will have to take into account the goals set by the financial department. The information system will have to keep track of which customers the company has approached. The product design will be based on the expectations of the customer, who will see this reflected during the sales process. The customer can then proceed to buy the product. The information system will need to maintain a list of each product sold with details

such as product type, estimated period of use of the product, customer contact details and date of purchase which it collects from the sales department and from the customer.

The blueprints produced by the product development department will let the information system know after how much time the product has been consumed on average. In the case of consumer products, this estimate is made in such a way that, after the consumption period, all used, degraded parts or materials can still be recycled (e.g. catalyst in carpets). In the case of used products, information technology will monitor this via sensors and the like placed in the product. This information technology will then have to record certain data determined in the blueprints on the basis of the characteristics of the product (e.g. mileage in a car).
By combining this with the information that the information system receives from the sales department, the information system can know at which customer the product is almost consumed and thus ready to take back. This allows the take-back department to address these customers for the take-back of their products. When the customers return their products, the company will assess their quality. The information of goods that still have sufficient quality, or are still able to be recycled, are transferred with their characteristics to the recycling department. If there are certain things that cannot be recycled, external partners will be addressed.

As mentioned earlier, the processes and machines used in the recycling department determine the product design. On the other hand, the product design will have to communicate which items of the product they have foreseen to be recycled through which recycling process. From the take-back department, information will be obtained about the taken back products that are thought to be recyclable, these products are already subject to a quality control based on used standards. Once the recycling department has recycled the recyclable products, these products and their information can be sent to the input department so that they can be re-introduced into the production process. It will be the role of the information system to keep track of all data from the recycling department regarding actual costs, productivity, recycling rate, and so on.

It is the task of the information system to ensure that each role within the company has sufficient information to fulfil its tasks. To do so, the IS will not only have to distribute information, but sometimes also process it itself. The table below gives an overview of the identified information flows.

Product design		
In	Customer	Requirements and expectations
In	Recycling	Specifications used machines and processes
In	Input	Possible sources
Out	Input	Necessary inputs for the product
Out	Manufacturing	Blueprint of the product its manufacturing process
Out	Recycling	Blueprint of the recyclable parts
Input		
In	Sources	Different possible suppliers of input
In	Product design	Product requirement
In	Finance	Budget
In	Governance	Policies on partnerships
Out	IT	Actual costs, inventory, partnerships, …
Out	Manufacturing	Inventory of resources available for manufacturing
Manufacturing		
In	Product design	Blueprint of the product its manufacturing process
In	Governance	Standards for working conditions
In	Inputs	Available inventory
In	Finance	Budget
Out	IT	Actual used inputs, finished products, costs, stocks, …
Out	Sales	Finished products available for sale
Sales		
In	Manufacturing	Available finished products
In	Finance	Objectives
Out	IT	List of all addressed prospects, clients, number of sold products, …
Customer		
In	CRM	Sufficient contact points to keep the customer connected to the (circular) company
Out	Product design	Requirements and expectations
Out	IT	List of each product sold with details such as product type, estimated period of use of the product, customer contact details and date of purchase
Take back		
In	IT	List of customers where the product is almost completely used and thus ready for takeback
In	Customer	Information of products that are ready to be taken back
Out	Customer	Information on how the takeback process takes place
Out	Partner Out	Characteristics of taken back products that cannot be recycled.
Out	Recycling	Characteristics of taken back products can be recycled.
Out	IT	List of taken back products and their characteristics (reporting)

Recycling		
In	Take back	Characteristics of taken back products that can be recycled.
In	Product design	List of items per product that are foreseen to be recycled
In	Quality	A list of the taken back products that meet the quality standards.
Out	Inputs	Prediction of the recycled products as resource
Out	Product design	Specifications used machines and processes
Out	IT	List of data on actual costs, productivity, recycling rate, ect.

Evaluation

The master thesis allows for some aspects of evaluation. The aspects of validity and utility were addressed (Hevner and Gregor, 2013). The final model described in this master thesis is based on both literature sources and practical aspects. In terms of validity, it can be stated that the model was evaluated throughout the interviews and after. During the interviews, the interviewees were asked about their thoughts in the current model in the end of the interview. The final model was checked for feedback at the interviewed companies through mail; 2 out of 5 companies replied that the model was relevant and one company could even notice a missing relationship. The contributions provided in this master thesis for organizational teams are certainly useful as it answers a question that has not been researched before and has a clear practical relevance. In further research, the model itself can be implemented within a company in order to have a proof of concept and thus an excellent picture of the utility of the artifact.

Contributions

Answering the research goal of this work, this research has made 3 contributions:

- Foundation for future research on this topic
- A model of the actors, their role and interconnectivity, present within a circular business environment and the information flows between them
- Non-exhaustive list of information flows as foundation for organizational teams

In this study, qualitative research was carried out to provide an answer to an existing research gap. This gap is the lack of information about the relationship between information systems and the circular economy. This research is relevant because the transition from a circular to a linear economy becomes necessary as the current linearity can no longer be maintained. There is a growing call for circular models for personal reasons from managers of companies, the consuming population, governments, ect. but there is nowhere any mention of how companies can do this. This master thesis partly tries to answer this question by investigating the role of information systems. It has

been proven that the use of an information system within a circular model could provide additional benefits for the company.
In order to find an answer to this knowledge gap, a design science research method was followed in which a model was first drawn up on the foundation of the literature. Afterwards, an iterative method was applied in which both interviews, thus practice, and literature, thus theory, were addressed. Finally, the final model was forwarded to the interviewed companies to find out whether the model was representative. In terms of validity, it can be stated that the model was evaluated throughout the interviews and after. Both theory and practice was implemented in the model.

This master thesis has implications for the research area as well as for organizational teams. This master thesis lays the foundation for future, both qualitatively and quantitatively, research on this subject. The artifact itself is also a major research contribution as it answers to the level 1 knowledge contribution; Situated implementation of artifact, which is the model of the actors, their role and interconnectivity, present within a circular business environment and the information flows between them. Elaborating the DENICA method resulted in a system of roles and accountabilities with information flows between roles that are not only located within a company but that extend to an entire company and its business ecosystem. However, the main implication of this master thesis is the result of the artifact addressed for organizational teams. As this master thesis implements the DENICA method, it results in a model of the actors, their role and interconnectivity, present within a circular business environment and the information flows between them. This model resulted in a non-exhaustive list of information flows, as discussed in the Discussion section, for organizational teams that is considered necessary for enterprises in a circular economy and identifies possible risks where the process may go wrong. In order to transform this list into an exhaustive list of information flows, the information flows between the roles of the model that are not described in this research should also be discussed. However, once all these information flows have been discussed, it should be taken into account that each company will still have company-specific information flows.

The findings of this study have to be seen in light of some limitations. There are two major limitations that could be addressed in future research. First, it is possible that the generalization of the drawn models and their results is not valid due to the rather small sample size of interviewed companies at different levels of hierarchy. By interviewing more companies with more similar profiles of employees within the companies, studies will give insights in a more diversified field of industries and might quantify better the actual nodes by measurements. The second limitation of this study is the time frame. The study needed to be done before a specific deadline and this limited the number of interviewed companies and furthermore the time deadline prevented the model to be fully tested at

an independent company. As mentioned in the evaluation section; the model itself can be implemented within a company in order to have a proof of concept and thus an excellent picture of the validity of the artifact.

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Attachments

1. List of addressed companies

This is the list of all the 53 companies who were listed based on their location and most important activity. These companies were found on Google Maps, the network of the author or on sites about circularity (https://vlaanderen-circulair.be/nl/kennis/ondernemen-in-de-circulaire-economie; https://www.c2cplatform.be/inspiration/). The companies indicated in red were the ones that were finally addressed with the question if they could make time for an interview.

1. Artislach
2. Atlas Copco
3. BC Architecten
4. Bebat
5. Bexco
6. BMA Ergonomics
7. Bontexgeo
8. Bureau 9000
9. C&A
10. Callebaut
11. CRC Industries
12. CREPISCO
13. De Kringwinkel
14. De Smaele
15. De Verffabriek
16. Drylock Technologies
17. DS Smith Packaging Belgium
18. DS Textile Platform
19. Duvel Moortgat
20. Empro Europe
21. Envisan
22. Facadeclick
23. Flexso
24. Galloo
25. Glimps
26. H&M
27. Honda
28. Ijzerwaren De Balans
29. Jan De Nul
30. JBC
31. Kodibox
32. Lammens Recycling
33. Lotus Bakeries
34. Molcon Interwheels
35. Oleon
36. Omco Metals
37. Ontex
38. Partago
39. Raemdonck PVC
40. Recupel
41. Roltex
42. Samsung
43. Stone Living
44. Sura
45. Tarkett – Desso
46. Tech Data
47. Too Good To Go
48. Tupperware
49. UCB
50. VDB Frozen Food
51. Vondelmolen
52. VPK
53. Ziegler NV

Table 1: List of addressed companies (Source: author)

2. Semi-structured interview: Starting questions

A. General information company
    a. Can you provide some background information on the general activities of the company?
    b. Why are you involved in circular processes? What is the influencing factor? (personal conviction, financial, emergency demand side
    c. What products/projects do you have that comply with circularity?
B. Specific questions about CE and/or IS
    a. How does the process of this product work for you? Which milestone/parts in this process are crucial?
    b. Which aspects are crucial for you to assess these processes? (are they different from other projects or not?)
    c. How is your circularity tracked?
    d. How is the use of information systems situated in the circular process?
    e. What decisive information does the information system process?
C. Current model
    a. What do you think about the model? Do you have additions or remarks?

3. Analyses of the companies in the CBMC framework

An overview is given in the table below. For each aspect of the CBMC model, the extent to which they comply with this model is examined for each individual company. A / means not applicable, -- means that they do not meet this characteristic at all, - means that they do not meet previously, + means that they do meet previously, ++ means that the company fully meets this characteristic.

	Company 1	Company 2	Company 3	Company 4	Company 5
Industry	Energy consulting	Flooring industry	Dredging and maritime works	Paper recycling	Software consulting
Partners	+	++	-	++	+
Activities	/	++	-	++	/
Key resources	+	++	+	++	+
Value proposition	/	++	--	++	/
Customer relations	/	++	+	++	/
Channels	++	+	-	+	++
Cost structure	-	++	++	++	/
Revenue streams	+	++	++	++	/
Takeback system	/	++	--	++	/
Adoption factors	++	++	+-	++	-+
Customer segments	+	+	-	++	+

Table 2: Analyses of companies in the CBMC framework (Source: author)

Company 1

Value proposition:

The overarching goal of this company is to achieve a more sustainable future by advising its customers in various manners. One of these four different methods is to guide the customer towards a co 2 neutral future. It is not circular in nature itself, but it does help other companies, as a partner, in this transition.

Channels:

The company works entirely in the cloud and minimizes its paperwork as much as possible. Something like this has already managed to stop printing certain products and hand them over a scrap of paper and to do this virtually on a USB stick.

Customer segments:
The customers of this company in the co2 neutral domain are relatively limited.

Customer relationship:
Company 1 has no specific marketing campaign for its CO2 neutral future but most of its daily activities is service on order based.

Revenue streams:
Company 1 does not does not gain most of it revenues through there CO2 neutral service but this service would be a demand fulfilment product as a service.

Key resources:
This company will help other companies in the search for renewable sources in the optimal deployment of, for example, solar panels. They will also make maximum use of renewable sources in their own offices.

Key activities:
The company does not comply with the circular key activities within this model.

Key partnerships:
This company can even serve as a partner for other companies that want to move towards a CO2 neutral future.

Cost structure:
This circular aspect is not applicable to company 1.

Take-back system:
This circular aspect is not applicable to company 1.

Adoption factors:

Both motivation, knowledge and willingness to implement a circular economy are present. The internal adoption factors are therefore present. The co 2 neutral advice story is less in demand than the other services of the company. This consultancy agency is mainly approached for advice on energy efficiency or renewable energy. One can therefore say that the external factors for this company are partially filled in.

Company 2

Value proposition:

Company 2 its value proposition is ownership based. The company's product is modularly designed and can be largely recycled. Therefore it meets the requirements of the CBMC.

Channels:

This company uses virtual communication wherever possible.

Customer segments:

There is a very good fit between the customers of this company and the value proposition that is going to present itself.

Customer Relationship:

No specific bonds with the customers of this company were made but they do have a specific marketing behind their circular product. They do believe that this circular product gives them a competitive advantage towards their competitors.

Revenue streams:

When the company recycles its products, by-products will be created that the company itself should not reuse in the recycling of its own product. These can be sold and thus generate additional income. Furthermore, the company also has a very good overview of how it can sell possibly recycled products as new products.

Key resources:

The entire output of this company will be used as its own input through a number of other partners. This means that the company will do circular sourcing. It will also use as many renewable sources as possible and reduce the input it uses from nature to a minimum. In order to limit the use of natural resources, such as water, the company will also set annual targets that can be found in the annual sustainability report.

Key activities:

Year after year, the company tries to improve its performance, this will also be monitored every year. The company has created the product design for most of its products, enabling it to work more efficiently.

Key partnerships:

A collaborative network has already been built up in which this company can rely on partnerships in the collection of its main input. A key activity within the circular aspect of this company is also carried out by a partner with whom it has very good relations.

Cost structure:

The main costs related to the circular aspect of this company have been identified. All input is used optimally.

Take-back system:

Thanks to the partnerships within the company's cooperative network, the company is able to close its circle. Company 2 does this on the basis of forward logistics. They motivate the customer to return the goods to the partner when the product is consumed.

Adoption factors:

It is the core business of company 2 to work circularly. The internal adoption factors are therefore all fully present. Both in terms of motivation, knowledge and necessary transitions are sufficiently and fully carried out by almost every employee. In terms of external factors, company 2 fits well as well. One notices that there is an increased demand for the circular products and that the regulations of the country will also support this. There is no unified IT yet but so far this is not a problem.

Company 3

Value proposition:

This company does not yet find its value in the circular aspect, their value proposition lies in meeting the customer's demand as well as possible. However, this does mean that if the customer has a specific need for this, they will want to do so. They themselves notice an increased demand for this and this can lead to a final switch.

Channels:

This company does not use virtualisation.

Customer segments:

the main reason why this company started up the csr department is because the demand came from the market. It can therefore be said that this company lags slightly behind its customers.

Customer Relationship:

Company three marketing is focusing on CSR as they are improving their CSR activities.

Revenue streams:

It is currently being considered how some mined products during projects should not be considered waste but can be resold. This process is still in its infancy.

Key resources:

The company realises that it must use its energy as sparingly as possible and will now try to save on natural inputs in order to do its bit towards nature.

Key activities:

The recently started CSR project to obtain more sustainability within the company has already ensured that it is trying to increase its performance. The more efficient use of energy is an example of this.

Key partnerships:

No cooperative network has yet been found, but possible partnerships are being looked into. The first steps in this process are being taken and exploratory talks are taking place.

Cost structure:

The costs of this company are closely monitored. The company strives for optimal and efficient deployment in all its processes.

Take-back system:

Company 3 does not have to take back products from the customer as it is rather a services company. The products that it could get in a circular system are products that it will mine itself.

Adoption factors:

There has been a mental switch within the company in recent years. The start-up and development of a CSR department allows us to conclude that the internal adoption factors have been met. However, the external adoption factors within this company cannot yet be met.

Company 4

Value proposition:

Company four is very advanced in its circular value proposition. The company's product is modular and ownership based, so the customer currently still obtains ownership. However, a concept is currently being developed in which they are switching to a value proposition that is no longer ownership based. In the future it would like to switch to product as a service.

Channels:

This company uses virtual communication wherever possible.

Customer segments:

There is a very good current fit between this company's customers and the value proposition it presents itself. At the moment we are also looking at how the market will behave towards the product if a service wants to implement it in the future.

Customer relationship:

No specific bonds with the customers of this company were made but they do have a specific marketing behind their circular product. They do believe that this circular product gives them a competitive advantage towards their competitors.

Revenue streams:

When the company recycles its products, by-products will be created that the company itself should not reuse in the recycling of its own product. These can be sold and thus generate additional income. Furthermore, the company also has a very good overview of how it can sell possibly recycled products as new products.

Key resources:

The entire output of this company will be used as its own input through a number of other partners. This means that the company will do circular sourcing. Unfortunately, the company has not yet found a way to fully recycle all of its products. It is trying to substitute it with other goods that are less harmful to nature. Optimal use of natural resources is the company's primary concern.

Key activities:

The company has created the product design for most of its products, enabling it to work more efficiently. The company hopes that in the future competitors will have to adopt their way of working and thus gain a competitive advantage in the future (lobbying). To this end, it will be very transparent in its processes towards the government.

Key partnerships:

A cooperative network has already been built up whereby this company can make use of good partnerships for both its inputs to the recycling process and for possible outputs that it cannot use itself.

Cost structure:

The main costs related to the circular aspect of this company have been identified. All input is used optimally.

Take-back system:

Thanks to the partnerships within the company's cooperative network, the company is able to close its circle. Company 4 does this on the basis of reverse logistics. They motivate customers to return the same product to the company after consuming it.

Adoption factors:

For several years now, Company 4 has switched from a linear to a circular way of thinking. There is a clear motivation from the management of the company and in recent years the right knowledge has been amassed to get to where they are now, although they still need to build up additional knowledge. The right information system has already been implemented but they have not yet noticed any increase or specific demand from the industry. It can be said that for this company both the internal and external adoption factors are reasonably well met.

Company 5

Value proposition:

The value proposition of this company has no circular background.

Channels:

The company works entirely in the cloud and minimizes its paperwork as much as possible.

Customer segments:

Currently there is a very good coordination between the company and its customers. She is even trying to get a head start by already investigating circular information systems.

Customer relationship:

Company 5 has no specific marketing campaign for its service but most of its daily activities is service on order based.

Revenue streams:

This company does not derive its income from a circular process or from recycling.

Key resources:

Company 5 wants to use its resources as efficiently as possible and will find alternative ways for certain emissions such as replacing the car with a scooter in urban areas.

Key activities:

The company does not comply with the circular key activities within this model.

Key partnerships:

This company itself serves as a partner for other companies in guiding them from their current information system to a circular information system.

Cost structure:

This circular aspect is not applicable to company 5.

Take-back system:

This circular aspect is not applicable to company 5.

Adoption factors:

The right knowledge is researched in order to be able to help our own customers as good as possible with their external adoption factor information systems. An increased demand for circular information systems has been noticed and the internal motivation to meet this demand is present.

Conclusion

When we look at the companies as a whole again afterwards, we notice that mainly company 2 and company 4 comply with most of the circular aspects within the CBMC model. Company 3 does not meet the model for the time being, but this is mainly because this company is still in the start-up phase and within a short period of time this company will also be much more circular in nature. As expected, Company 1 and Company 5 do not comply with the circulated aspects of the model, but these were rather addressed on the basis of their specific knowledge on a certain theme.

4. Analyses of the companies in the Butterfly diagram

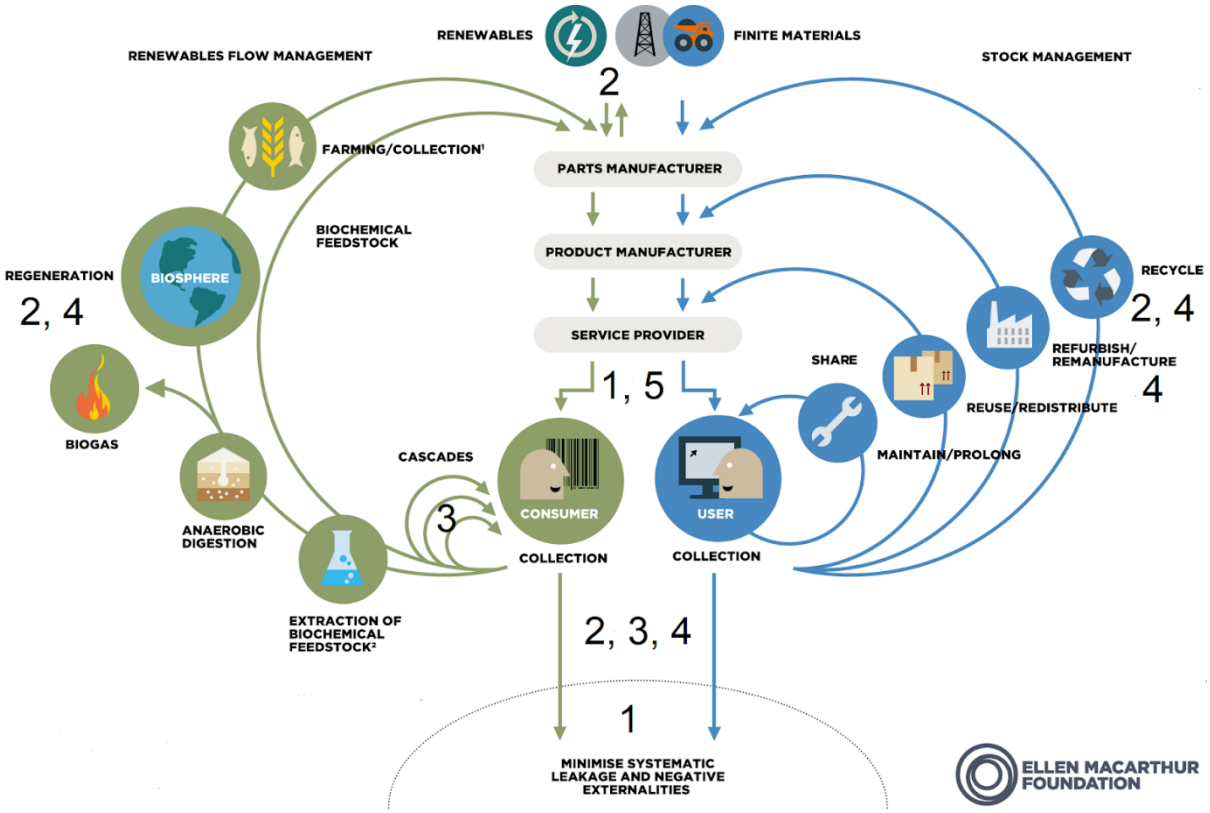

Figure 6: Analyses of the companies in the Butterfly diagram (Source: author)

The butterfly diagram was extensively discussed in the literature review. In this section the interviewed companies are placed within the butterfly diagram based on the qualitative interview that was conducted with them. The result is shown in the picture above. For each company an explanation is given below.

Company 1

Company 1 is not directly circular in nature. It is a study and energy consultancy that will help other companies in their way to their CO2-neutral future. In the Butterfly Diagram they are therefore placed on 'minimizing systematic leakage and negative externalities' because they are going to help companies with circular or sustainable thinking to reduce these leakages and negative externalities.

Company 2

Company 2 is featured more in the butterfly diagram. the company will initially try to use as little energy inefficient as possible (minimise leakage). It is also in the company's DNA and core business to recycle paper and cardboard and put them back into circulation (recycle). In recent years, however, they have been able to improve this process and now they can already get certain raw materials they use back into the system through extraction (regeneration). The company has also referred to certain initiatives that, as a result of partnerships with other companies, make it possible for certain products to be used more than once by the consumer before the recycling process is started (reuse). In the production process of cardboard boxes or paper products, a great deal of residual waste is

generated. However, this residual waste is considered valuable and can sometimes be used to make other products (cascades).

Company 3

Company 3 is mainly known for its dredging and maritime works. This multinational company achieves an immense annual turnover and is currently implementing a new, more sustainable future. A first step they have taken is to minimize negative externalities on their energy absorption in order to achieve a more efficient energy consumption (minimise leakage and negative externalities). As a service company it is difficult to answer other questions within this butterfly diagram, but this company tries to use as much renewable energy as possible and to use their materials as optimally as possible (renewables). Possibilities for partnerships have already been discussed in order to rework possible current waste materials into new products (cascades) in the future.

Company 4

Company four also appears several times in the butterfly diagram of the Ellen MacArthur Foundation. Just like the three previous companies, they also try to minimize their energy consumption (negative externalities). Within their circular process, they actually very quickly check whether the product they are going to replace at the customer is recyclable. They themselves have developed and designed their product in such a way that it is recyclable at the end of its life cycle (recycling). Their technological materials consist of various biological materials that they can bring back into the system after recycling through partnerships with other companies that can use these, for company four, waste materials as a source (regeneration). For their own incoming sources, these companies also collaborate with other companies. The company can also be located within the remanufacture loop because it can bring some products back onto the market with adjustments (remanufacture).

Company 5

Company 5 is a service company that implements software applications at its customer's site. This company does not produce any products and therefore it is more difficult to fit into the butterfly diagram. This company was interviewed about its knowledge of information systems and not so much for being circular. They also notice an increase in the demand for information systems to support a circular economy.

Conclusion

After we have tried to place the 5 companies within the butterfly diagram, we can draw the same conclusion as with the CBMC model. We see that company 2 and company 4 appear more often in the model and we also see them in both the biological and technological materials loop. Company 3 already comes up a little more here. As company 1 and company 5 are partners for the transition towards a circular economy for other companies, they are less represented in this model which gives the same conclusion as the CBMC model.

5. SNA measurement: influential factors

Degree centrality

	Supplier	Nature	Partner in	Shareholders	Finance	Governance Firm	Marketing	CRM	Transport	HR	IT	Partner out	Quality contr	Product Desig	Inputs	Manu-facturi	Recycling	Sales	Takeback	Customer	Degree centrality
Supplier	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Nature	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Partner in	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Shareholders	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Finance	0	0	0	1	0	1	1	0	0	0	1	0	0	0	1	1	0	1	0	0	7
Governance Firm	0	0	0	1	1	0	0	0	1	1	1	0	1	0	1	1	0	0	0	0	8
Marketing	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	3
CRM	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	3
Transport	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2
HR	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
IT	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	0	8
Partner out	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Quality control	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	3

Table 3: SNA degree centrality (Source: author)

Closeness Centrality

	Supplier	Nature	Partner in	Shareholders	Finance	Governance Firm	Marketing	CRM	Transport	HR	IT	Partner out	Quality control	Product Design	Inputs	Manu-facturing	Recycling	Sales	Takeback	Customer	Closeness
Supplier	0	2	2	3	3	2	3	3	3	3	2	4	3	2	1	2	2	3	3	3	**49**
Nature	2	0	2	3	3	2	3	3	3	3	2	4	3	2	1	2	2	3	3	3	**49**
Partner in	2	2	0	3	3	2	3	3	3	3	2	4	3	2	1	2	2	3	3	3	**49**
Shareholders	3	3	3	0	1	1	2	3	2	2	2	4	3	3	2	2	3	3	3	4	**49**
Finance	2	2	2	1	0	1	1	2	2	2	1	4	2	2	1	1	2	1	2	2	**33**
Governance Firm	2	2	2	1	1	0	2	3	1	1	1	3	1	2	1	1	2	2	2	3	**33**
Marketing	3	3	3	2	1	2	0	1	3	3	2	4	4	2	3	2	4	1	3	2	**48**
CRM	3	3	3	3	2	3	1	0	4	4	2	3	3	2	3	3	1	2	2	1	**48**
Transport	3	3	3	2	2	1	3	4	0	2	2	4	2	3	2	2	3	3	3	4	**51**
HR	3	3	3	2	2	1	3	4	2	0	2	4	2	3	2	2	3	3	3	4	**51**
IT	2	2	2	2	1	1	3	2	2	2	0	2	2	1	1	1	1	1	1	2	**31**
Partner out	4	4	4	5	4	4	4	3	4	4	2	0	2	3	4	4	2	3	1	2	**63**
Quality control	3	3	3	2	2	1	3	3	2	2	2	2	0	3	2	2	1	3	1	2	**42**

Table 4: SNA closeness centrality (Source: author)

6. Iterative method

First model

The first model was drawn up on the basis of read literature and our own findings. Here I decided to make a distinction between the internal and external components. The first roles and how they are interconnected were mapped without giving direction to information flows.

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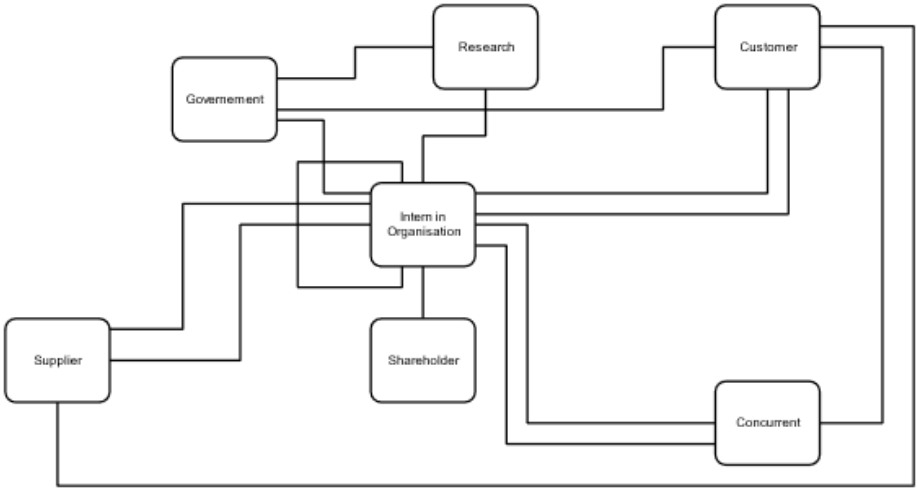

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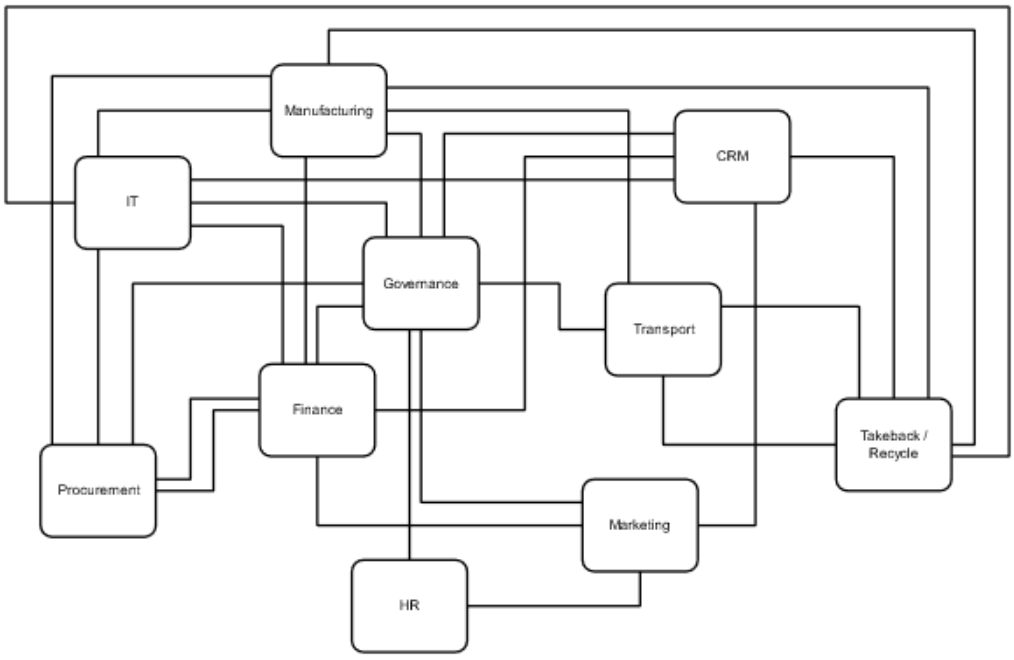

Figure 7: First model (Source: author)

Second model

The first model, based on literature and own findings, was tested for the first time by means of an interview at company 1. The knowledge of this company was used to confirm or deny the identified roles, as this partner for circularity would have knowledge of these roles. As a result of this interview I (1) was able to situate the direction of influences and information flows and (2) additional actors

were suggested. These actors were searched for in the literature after the interview but were not specifically found, which is why I did not put them in the second model but did check them during the other interviews.

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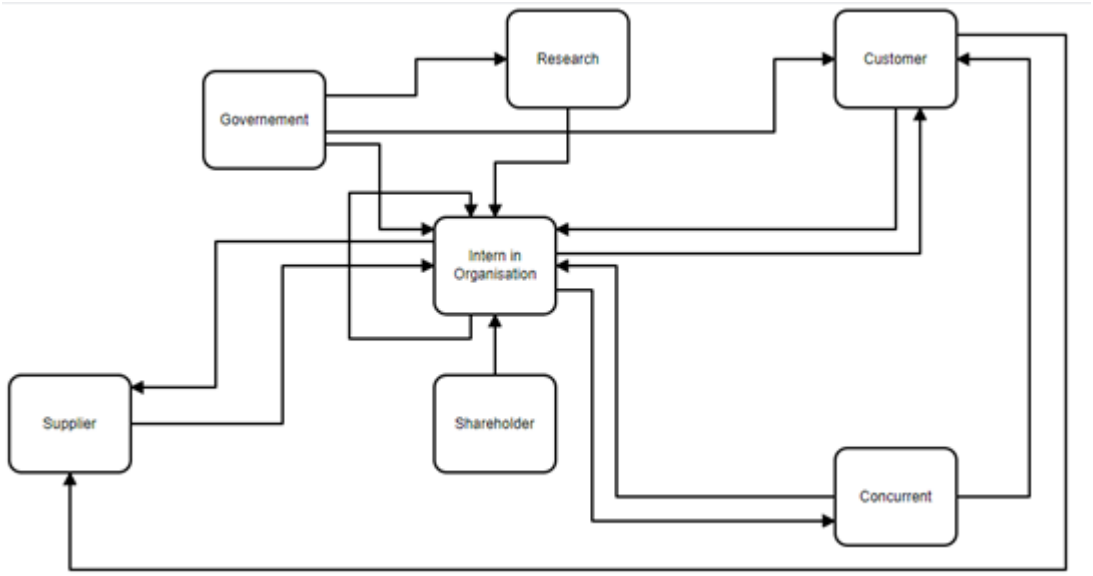

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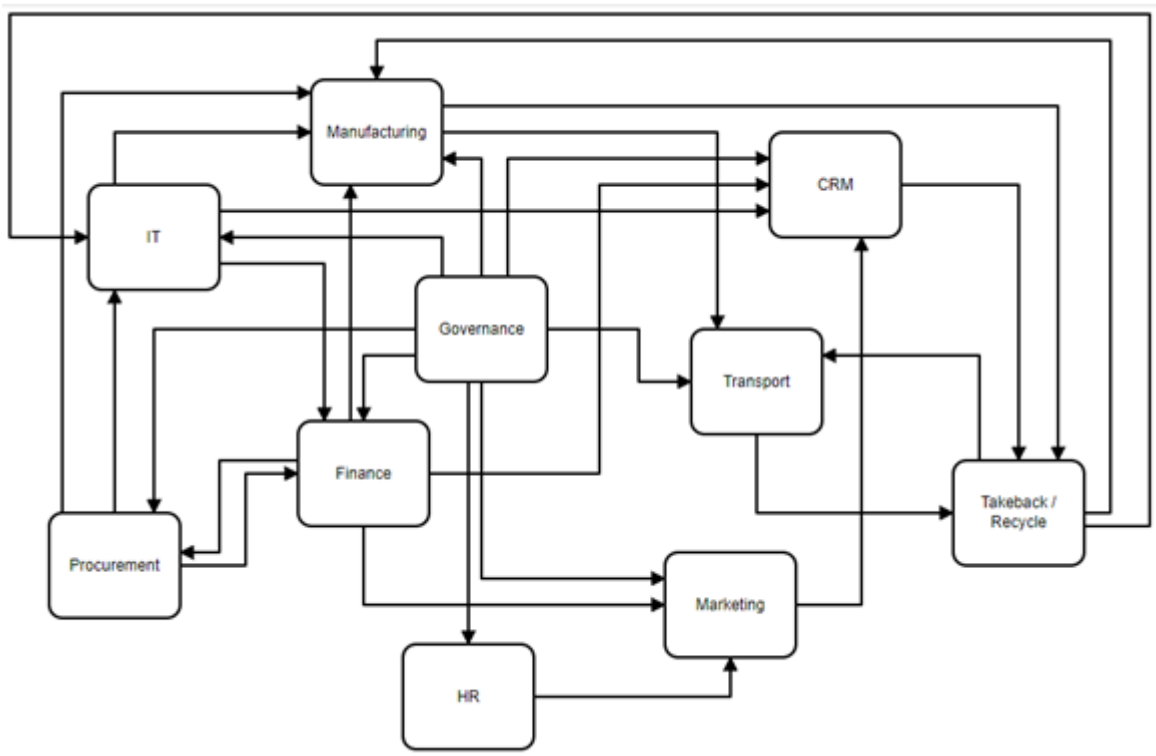

Figure 8: Second model (Source: author)

Third model

During the interview with company 2 and company 3, they were asked to explain their circular process and the modelled components were also questioned. Afterwards, these companies were

then asked about the additional components that company 1 identified and whether this was also important in their process. This ensured for example that the component control organism was included in both the external and internal diagram. The internal model was redrawn in order to distinguish more clearly between the circular process and the influencing roles. Other internal roles were added due to those interviews. Company 4 and company 5 were interviewed with this adjusted model and they confirmed that every component in the diagrams are important and should be in there as they all are involved in their own processes as well.

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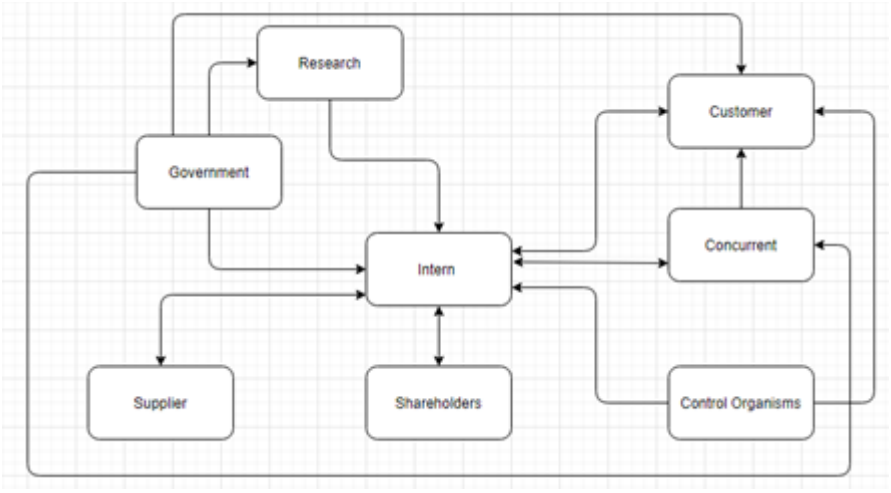

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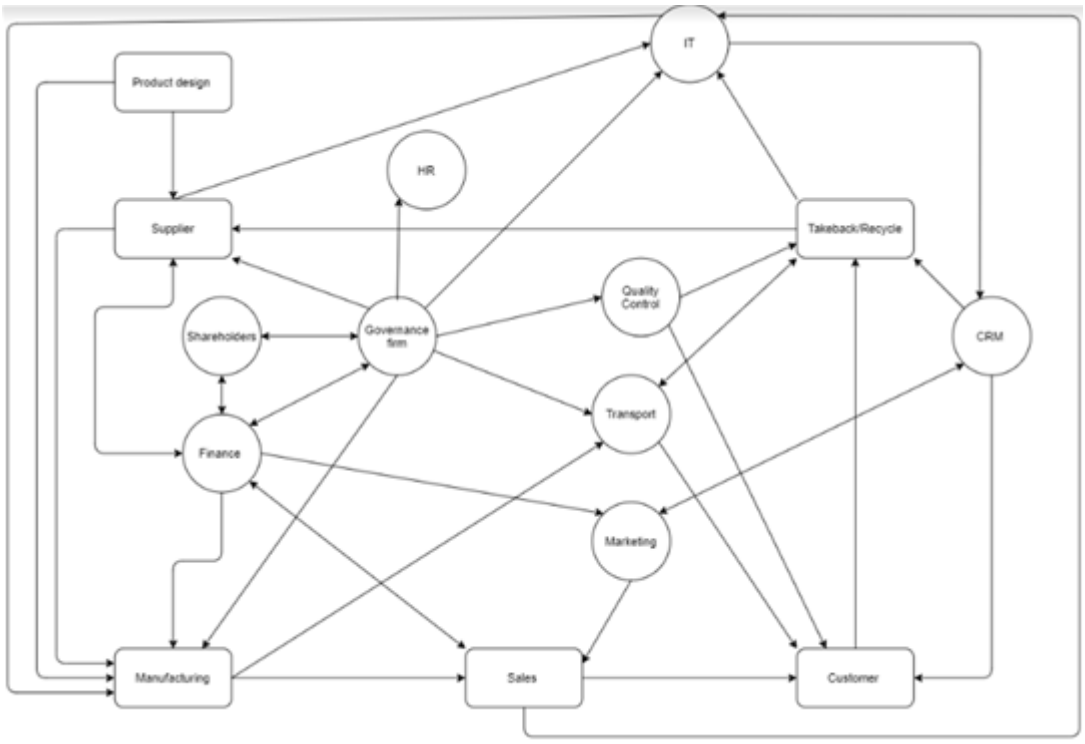

Figure 9: Third model (Source: author)

Fourth model

In order to obtain the third model, we mainly looked at the interviews that had been conducted, but after each interview we also looked briefly at whether these changes occurred in the literature. The transition between the third and the fourth model came after a thorough review of the literature. Papers were read about the sense & respond method and the DENICA method, which resulted, among other things, in the addition of levels. Furthermore, some relationships were clarified or referenced in the literature and some things were adjusted or added as a result of conversations with the mentor.

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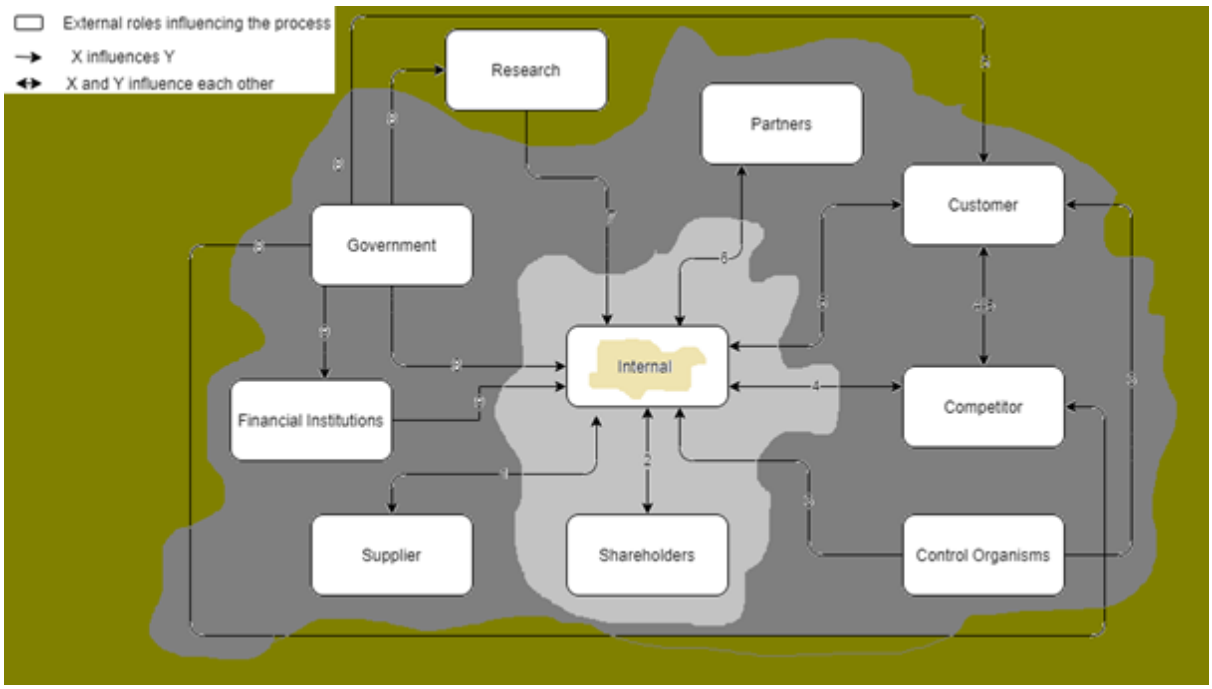

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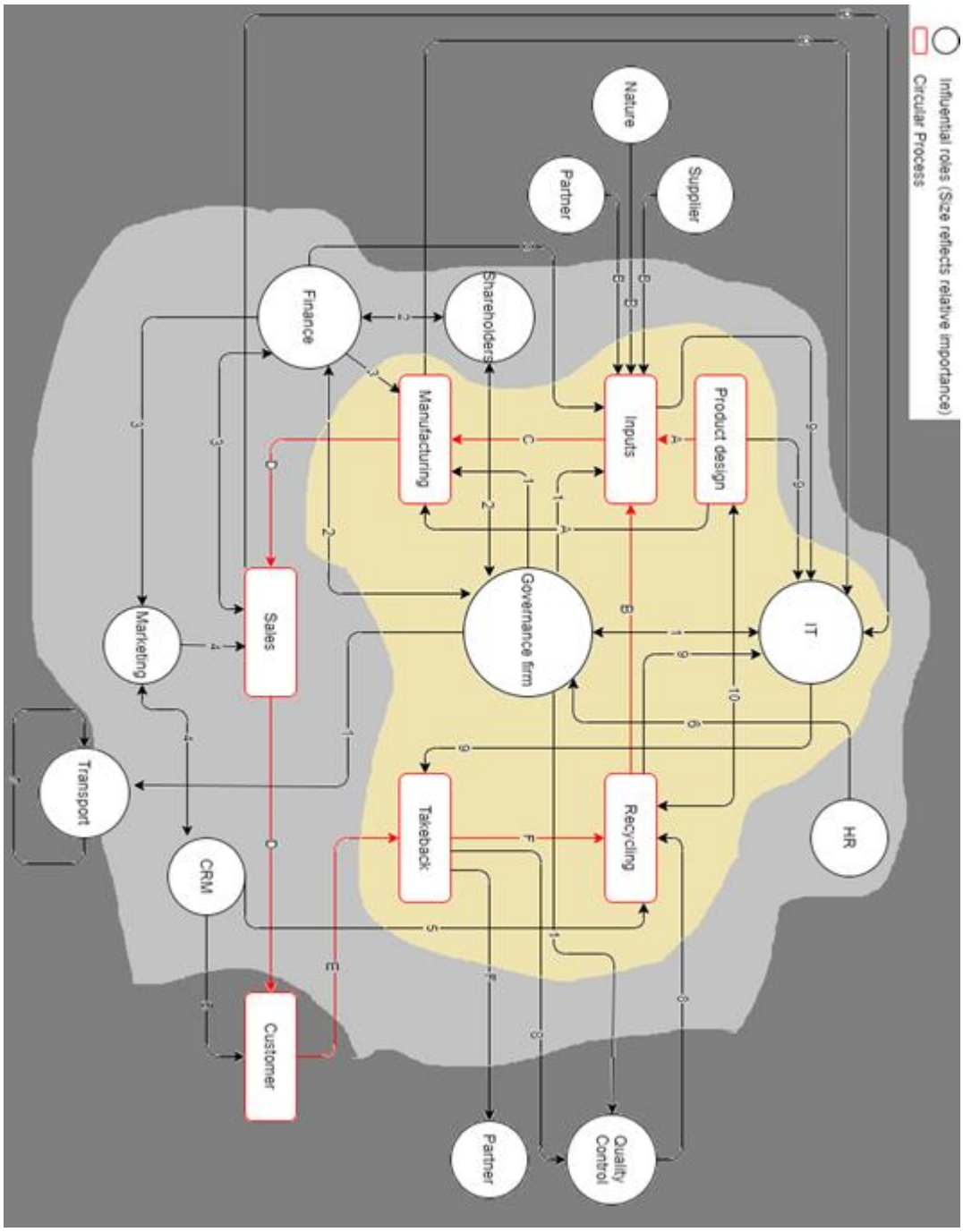

Figure 10: Fourth model (Source: author)

Fifth model

In order to draw up the fifth model, the interviewed companies were asked one last time to provide feedback. Because of the coronavirus, these companies were asked by mail if they wanted to give feedback on the 2 diagrams that are part of the fourth model. One company replied with the message that the model was very representative but that there might be another flow of information that was not in the model, i.e. the influence of the customer on the product design. This feedback from the practical experience was taken into account in this final model. Applying the SNA tactics,

which were found in the literature, ensured that the relative influence of the internal influential roles on the factors is correctly reflected.

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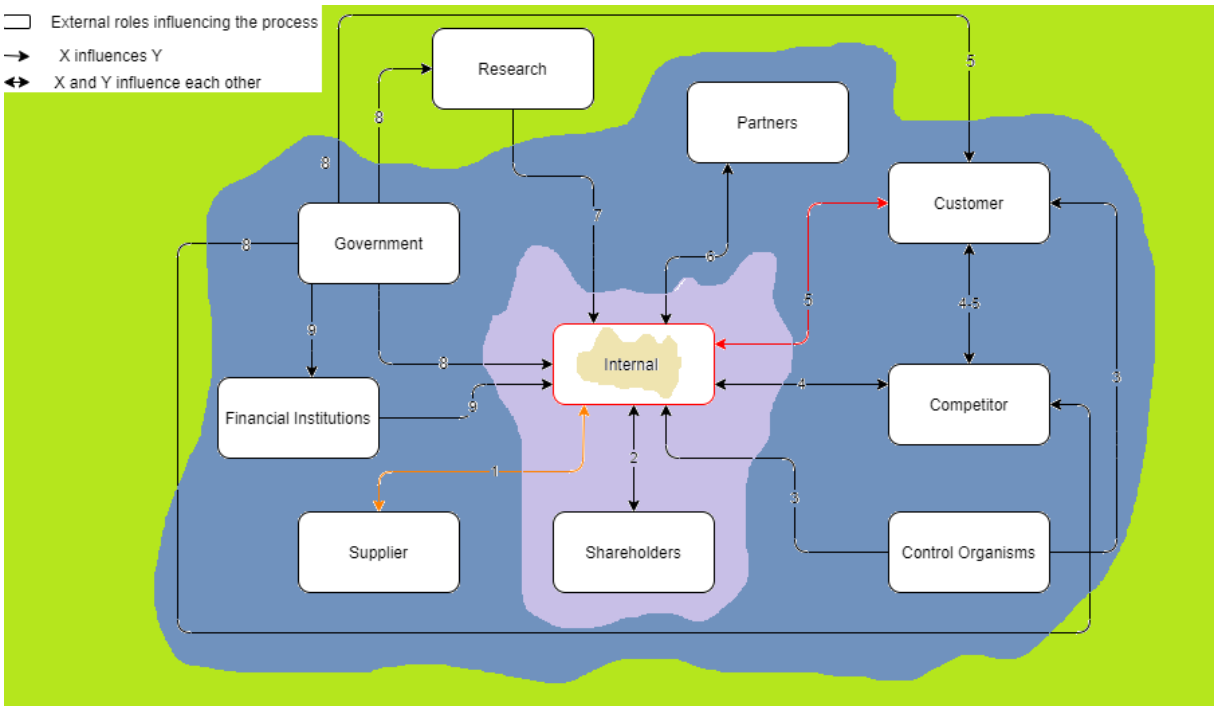

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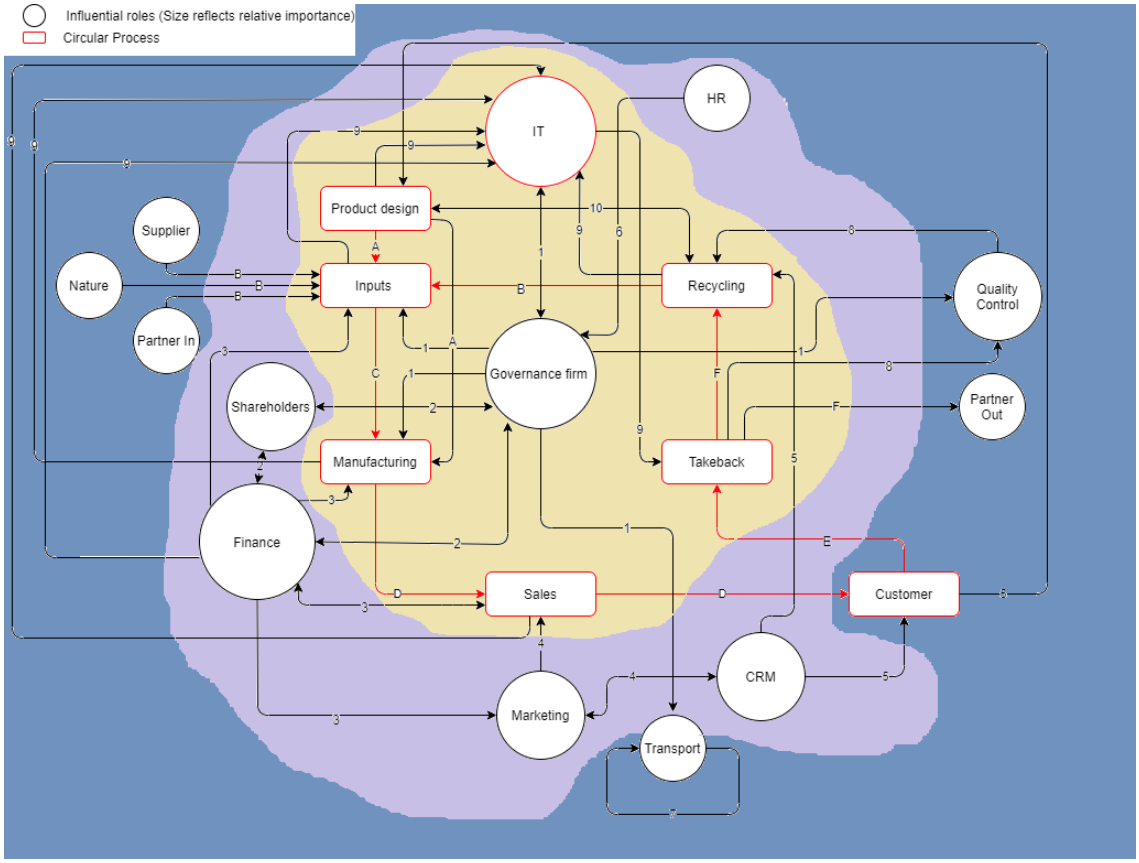

Figure 11: Fifth model (Source: author)