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MASTER THESIS

THE IMPLEMENTATION OF INDUSTRY 4.0 TO IMPROVE SUSTAINABILITY PERFORMANCE IN THE DUTCH CONSTRUCTION INDUSTRY

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Abstract: *The Dutch Construction Industry is currently facing challenges over its massive waste produced from their manufacturing process. The Dutch Climate Agreement also fosters the industry to serve the increasing demand for sustainable building material to achieve the energy transition. Hence, the construction industry in the Netherlands is exploring alternative means to address such sustainability challenges. By learning from the automotive and manufacturing industry, implementing Industry 4.0 can be an opportunity for the Dutch construction industry to become more sustainable. This thesis aims to conduct an explorative study on the implementation of Industry 4.0 in the Dutch Construction Industry to improve sustainability performance. To successfully implement Industry 4.0, the result suggested the industry to make a holistic change across business functions to ensure the balance between humans, characteristics of an organization, and new technology.*

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INTRODUCTION

The residential building is one of the major factors contributing to global warming since the energy used for heating accounted for three-quarters of the carbon emission (Tukker, Cohen, Hubacek, & Mont, 2010; Drukman & Jackson, 2016). According to the report on the great Dutch gas transition (Beckman & Beukel, 2019), 95 percent of residential buildings in the Netherlands are currently heated by natural gas. The use of natural gas can heat the planet as its unsuccessful burning process can leave unburned methane in the atmosphere, which creates greenhouse gas and worsening global warming (McKibben, 2018).

As a result, the Dutch Climate Agreement prohibits the use of natural gas in residential buildings to reduce carbon dioxide emission by 80 percent by 2050 (Ende, 2017). The fact that energy transition is emphasized in this climate agreement requires the residential construction in the Netherlands to achieve zero-energy building. Approximately 30,000-50,000 existing houses will be transformed toward fossil-free heating (Beckman & Beukel, 2019). Consequently, the demand for sustainable building material, such as insulation panels, will be increased (Ministry of Economic Affairs of the Netherlands, 2019). Hence, a construction company needs to adjust its business to produce more sustainable building material to serve such growing demand. Moreover, the construction companies will have to transform its manufacturing processes as the government called for a more responsive action on its production process that accounted for the largest part of the total wasted in the Netherlands (Circular Construction Economy, 2018).

By encountering similar sustainability challenges, industry sectors such as automotive and manufacturing are implementing Industry 4.0 to enhance their sustainability performance. Industry 4.0 is introduced by the German Federal state government as a strategic initiative plan for 2020 to advance the vertical and horizontal integration of production (Maskuriy, Selamat, Maresova, Krejcar, & David, 2019). The concept of Industry 4.0 is the use of emerging technology to facilitate the communication between people, machines, and resources enhancing the integration throughout the value chain (Wang, Wan, Li, & Zhang, 2016). This integration enables manufacturers to visualize and analyze real-time data, which leads to production optimization reinforcing economic competitiveness (Vaidya, Ambad, & Bhosle, 2018). Industry

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4.0 also contributes to the environmental and social impact development. The adoption Industry 4.0 technology helps reduce the resource and energy used in production and also lower emission produced (Bonilla, S.Silva, H.Silva, Gonçalves, & Sacomano, 2018). In the social dimension, the employees have the opportunity to advance their skills since the implementation of Industry 4.0 creates and increases new forms of employment (Kagermann, Wahlster, & Helbig, 2013). It also encourages a safer workplace, thus, increasing worker satisfaction (Braccini & Margherita, 2018).

By acknowledging the benefit of Industry 4.0, it is an opportunity for the Dutch construction industry to embark on this transformation to sustain the business. Although, there is a growing number of researches that conduct a literature study of Industry 4.0 in the construction industry. However, there are none of the empirical studies that demonstrate the implementation of Industry 4.0 for sustainability purposes (Maskuriy, Selamat, Maresova, & Krejcar, 2019). This kind of study is important particularly in the Netherlands, where the construction industry is demanded by the government and stakeholders to act more sustainably and responsively. To investigate solutions for this challenge, this thesis is, thereby, conducted to answer the research question of how can the Dutch construction industry implement Industry 4.0 to drive sustainability performance?

The purpose of this thesis is to provide an explorative study on the implementation of Industry 4.0 in the Dutch construction industry to iimprove sustainability performance. This thesis consists of five main sections. The first section provides an introduction that comprises a problem statement and objective of the research. The second part reviews relevant theories and literature on the concept of Industry 4.0, the sustainable outcome of Industry 4.0, the implementation of Industry 4.0 within the automotive and manufacturing industry, and the proposed framework for the implementation of Industry 4.0. The third section presents the methodology, case study profile, data collection, and analysis procedure. The fourth section presents the discussion of the result. The last section provides conclusions including limitations as well as the managerial and theoretical implications for further study in the field.

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THEORY

The Concept of Industry 4.0

The term Industry 4.0 has been coined in 2011 in the publication of the German federal state government on the high-tech strategic initiative plan for 2020 (Maskuriy, Selamat, Maresova, Krejcar, & David, 2019). The key concept of Industry 4.0 is the use of advanced technologies to create integration across the business and engineering processes for production to be operated in a more flexible, efficient, and sustainable way (Machado, Winroth, & Riberiro, 2019). The nine technological pillars in the implementation of Industry 4.0 consist of 1). Simulation, 2). Horizontal and Vertical System Integration, 3). Industrial Internet of Thing (IIoT), 4). Cybersecurity, 5). Cloud, 6). Additive Manufacturing (AM)-3D Printing, 7). Augmented Reality (AR), 8). Big Data, and 9). Autonomous Robots (Rüßmann, Lorenz, Gerbert, & Waldner, 2015, Erboz, 2017; Machado, Winroth, & Riverriro, 2019). Industry 4.0 technologies lead production to be vertically and horizontally integrated, which brings about efficiency and better economic competitiveness (Vaidya, Ambad, & Bhosle, 2018). The vertical integration refers to a tied-up of business function within the organization from production floor up through R&D, quality assurance, sale and marketing, and so on, while the horizontal integration implies the connection across the production floor and entire supply chain (Schuldenfrei, 2019). This integration provides better communication of functions within and outside the organization, hence, making production faster, more effective, and efficient with the real-time flow of information.

Pursuing Sustainability through The Implementation of Industry 4.0

Industry 4.0 could positively affect corporate sustainability by its extensive digitization that boosts productivity, and encourage resource and energy efficiency (Bonilla, Silva. H, Silva. M, Gonçalves, & Sacomano, 2018; Ghobakhloo, 2019). As predicted by the Boston Consulting Group (BCG), Industry 4.0 technologies will drive additional revenue growth of about €30 billion a year or 1% of GDP growth in Germany. According to the study of the International Federation of Robotics (IFR), automate robots can create a 0.04% increase in labor productivity and contribute to a 10% growth of GDP per capita in OECD countries from 1993 to 2016 (IFR, 2017). The real-time data analytic, as a result of the collaborative function of smart entities, Big Data, Cloud, and IIoT, can save production costs in many dimensions (Müller, Kiel, & Voigt,

2018). For example, it can reinforce the predictive maintenance of machine in the production line, which help reduce costly repair and unplanned downtime that can negatively impact revenue by 10-20% (Flex, 2020). Moreover, it also helps producers and suppliers to stay informed of the exact quantity of parts needed in production leading the company to stock appropriate amount of resources, hence, saving inventory cost (Bolland, 2018).

In an environmental aspect, Industry 4.0 facilitates the reduction of wasteful resource used, emission and encourages energy efficiency in the production process (Bracini & Margherita, 2018; Bonilla, Silva. H, Silva. T, Gonçalves, & Sacomano, 2018). Big Data analytic can lead manufacturers to obtain an accurate knowledge of the production process including product quality level. Hence, manufacturers can determine the quantity of raw material before production, which can limit the excessive use of a resource (Wang, Wan, Li & Zhang, 2015). Besides, Big data and Cloud also applied to support the use of the Energy Management System (EMS) to monitor and analyze real-time energy consumption that raises opportunities for energy saving (Sequeira, Carreira, Goldschmidt, & Vorst, 2014). The installation of smart machines that operate more intelligently will also reduce energy consumption in the production line (Wang, Wan, Li & Zhang, 2015). Furthermore, the digitization of a supply chain network provides a flow of accurate information that helps reduce wrong delivery and mistake in the order (Müller & Voigt, 2018). The decrease in delivery frequency leads to lower use of fuel consumption in transport, hence, limiting the possibility for emission to be produced in the atmosphere (Aktas, George, & Zissis, 2018).

Regarding the debate on whether the emerging technology would yield a negative impact on employment, the company that adopted Industry 4.0 argues that it encourages a new form of employment that allows workers to upgrade their skills (Kagermann, Wahlster, & Helbig, 2013). According to the World Economic Forum (2016), digital innovation and robotics will increase employment in terms of skilled technicians and specialists to manage the interaction between humans and machines. The high-skilled engineer and technician will be in high demand to ensure a well-managed function of IIoT and real-time data transfer. Besides, the implementation of Industry 4.0 advances safety among workers in manufacture. The research suggested the

adoption of Industry 4.0 reinforces a safer workplace and reduces workload leading to higher worker satisfaction (Braccini & Margherita, 2018). Based on the literature, Industry 4.0 seems to be beneficial for social development.

Industry 4.0: A Challenging Opportunity for Construction Industry to Improve Sustainability

According to the positive impact on sustainability, Industry 4.0 can be seen as the best way for the construction industry to grow sustainably. The fact that the construction industry involved complex, time-consuming building projects, and multiple production methods with excessive resources used require Industry 4.0 as a solution to transform complicated processes to be more effective and friendlier to the environment (Maskuriy, Selamat, Ali, Maresova & Krejcar, 2019).

The study by Alaloul, Liew, Zawawi & Kennedy (2019) view Industry 4.0 as an opportunity for the construction industry to cope with such complexities. With innovative technology, the construction industry can achieve time and material/labor cost reduction, the control level of waste produced, reduce energy consumption, and promote the innovative working environment. For example, autonomous help building companies to save labor costs and boost productivity (Delgado, Oyedele, Ajayi, Akanbi, Akinade, O., et al. 2019). The Additive Manufacturing will make it easier for the architecture to cope with complex building structure with its digital simulation function (Paolini, Kollmannsberger, & Ernst, 2019). By comparing with the traditional production line, Wang, Wan, Li & Zhang, (2015) also affirm that Industry 4.0 is the best solution to tackle problems, especially on time-consuming projects. The high-speed network infrastructure offers faster communication between machines, data, and people than a field bus, which use in the traditional production line. The installation of the self-organized machine can shorten one of the multiple methods in production as it works automatically unlike a traditional machine that requires staff to execute a step in pre-programming to function.

Industry 4.0 is not yet a reality in the construction industry even though many opportunities to achieve higher sustainability performance is acknowledged. This is because various factors limited its ability to be transformed. According to Bock (2015), the construction industry

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possessed the lowest capital, which obstructs R&D and innovative investment while Dallasega, Rauch & Linder (2018) viewed a fragmented supply chain, which consists of several small enterprise and SMEs, as a problem to innovate. Tay, Chuan, Chan & Alipal (2019) refer to the lack of knowledge in manufacturing technologies as another factor that constrains the construction industry to implement Industry 4.0. Furthermore, the unavailability of a clear roadmap and dedicated implementation strategy is also a reason why Industry 4.0 is still a dream for the construction industry (Maskuriy, Selamat, Ali, Maresova & Krejcar, 2019).

According to the survey from 100 construction companies, Alaloul, Liew, Zawawi & Kennedy (2019) argued that the biggest obstacle that influences the successful implementation of Industry 4.0 is the unique culture of the industry itself. This study can be supported by Kajewsk, (2002) that describe the construction industry's culture as overly protective that moving away from being a "risk-taker" or "innovator". Alalou, Liew & Zawawi (2016) also criticize the construction industry's culture over its reluctance to adapt as still operating in the way that it used to 50 years ago. This implies that embeddedness in a traditional way of working has become a norm that makes the construction industry uncomfortable or slowly embracing changes.

This brings about the assumption that the construction industry is encountering structural inertia, which is a barrier for organizational transformation to new development (Majid, Abdullan, Yasir & Tabassum, 2011). The structural inertia resulted from many forces include existing norms or procedure that the organization has established over time. (Hanna & Freeman, 1984), which require a proper change management strategy to tackle it. This led people to resistance to change to be one of the problems when pursuing opportunity from Industry 4.0 revolution (Horvath & Szabo, 2019). Regarding these obstacles, a suitable strategy for the construction industry to implement Industry 4.0 is still in the puzzle. The study from the existing implementation strategy to obtain know-how is, hence, necessary to produce the best strategy that fits with its particular context.

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Industry 4.0 Implementation Strategy by Sector

Automotive Industry

The automotive industry is realizing the potential of Industry 4.0 as always working to develop the innovation to serve the evolving customer's preference for safer, cleaner, and more efficient vehicles. The industry applies Industry 4.0 technology to enhance its competitive advantage through production and service. The observation study by Mueller, Chen, & Riedel (2017) demonstrates that intelligent sensors, which is the key component of IIoT, are used in Volkswagen. The sensor fosters Machine-to-Machine communication providing real-time data that enables machines to evaluate the best operating practice, which better reduces process faults and facilitates the decision-making process (Sumipol, 2017). Robots are another technology that is widely applied to assist manual tasks for better accuracy of the manufacturing process and delivery time of the product. For instance, the double-arm robot is used for material distribution process in the assembly line (Mueller, Chen, & Riedel, 2017) and a multi-arm robot is used to perform a complex type of assembly process with its flexible and high-speed operation competency (Kulkarni, Dhanush, Chatan, Gowda, & Shrivastava, 2019). Furthermore, the Additive Manufacturing (AM) is identified as a significant tool helping General Motor (GM) to reduce waste and downtime in parts production, as encountering complicated logistic systems, by printing components onsite at the final vehicle assembly line (Quinn, 2020).

The Augmented Reality (AR) is also applied to increase sales for Audy, Toyota and Jaguar Land Rover as it enables customers to gain a virtual perspective of a car's features and customizing their own version of the vehicle (Marr, 2019). According to Glowik, Mentuccia, & Tamietti (2014), the automotive industry develops cloud computing to store and support data analytic throughout the value chain from design, supply, assembly, retails to aftermarket service as facilitating the horizontal integration. For example, Renault developed a cloud supply chain platform to enhance integrative collaboration of supplier's networks worldwide to ensure accurate shipment, hence, reduce transport emission. BMW India's office introduced a smart video app-based solution to streamline its after-sale service to customers. This enables technicians to make a video of the vehicle's service requirement and allow customers to give real-time approval for service online (Davare, 2019).

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The automotive industry heavily addressed the cyber-attack issue to prevent data loss and disruption as a consequence of Cloud application. The collaboration through platforms such as US Auto Information Sharing and Analysis Center (Auto-ISAC), is identified as a key solution because the gathering has promoted a shared-knowledge platform on data security issues for the whole industry (McGinnis, Haberman, Schmith, & Robinson, 2020). Most importantly, the adaptation of Industry 4.0 cannot be achieved without potential human resources as Dutt, Natarajan, Wilsom, & Robinson (2020), address the necessity of investment to upskill employees to work in this digitalized era.

Manufacturing Industry

In the manufacturing industry, experts view competent employees as the most important factor in the success of Industry 4.0 implementation (Ghobakhloo, 2018). The management would first assess the digital skills among current employees and later give computer and IT training to enhance their competencies to work in an integrated virtual-reality environment (Darbanhosseiniamirkhiz and Ismail, 2012; Hecklau, Galeitzke, & Flachs, 2016). According to the study of Industry 4.0 implementation in the German manufacturing industry by Veile, Kiel, Müller, & Voigt (2019), strategy initiative on organizational culture and structure transformation are necessary. The management has the responsibility to motivate a new culture that embraces a willingness to learn, openness to new things, promotion of creativity, and endorsement of entrepreneurial mindset; tolerance to risk and customer-oriented. The management must underline agile, decentralized, and flexible organizational structure for smooth data flow across business functions to develop integrative systems.

In terms of marketing and sale, the industry focuses on real-time data-driven marketing to encourage co-creation and customization of products by addressing the benefit of blockchain and big data analytic based on social media (Dutta, 2014). For smart manufacturing operations, IIoT is implemented to digitized connections to integrate machines, databases, processes, and people (Gilchrist, 2016). The IIoT helps upgrade the function of the process controller's system called "Manufacturing Execution System" (MES). It could now operate at the advanced level that is

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capable of providing operational visibility and traceability through a real-time data integration platform. Digital services such as the Cloud also gain attention from manufacturers as a platform for data storage and analytic on cost as well as energy-saving (Ezell & Swanson, 2017).

Furthermore, supply chain management is transformed toward digital supply chain networks enhancing horizontal integration. Based on the study by Bienhaus & Haddud (2018), Big Data and IIoT are required to support full communication and knowledge-sharing between buyer and supplier resulting in data transparency and traceability. Another key success lies in IT governance effectiveness and infrastructure readiness such as network, computer, hardware, and software to ensure real-time communication of digital tools and smart objects (Gilchrist, 2016). Similar to the automotive industry, strict management to ensure cybersecurity is equally important. Veile, Kiel, Müller, & Voigt (2019) underline the balance treatment of data that should not be completely isolated to prevent the attack. The recruitment of white hat hackers and honeypots are suggested to search for security leaks and ensure the safety of the data (Kagermann, Wahlster, & Helbig, 2013).

Framework for the Implementation of Industry 4.0 for Sustainability

The Sociotechnical System Theory can guide the implementation of Industry 4.0 as it describes the system change that involves the interaction of humans, technology, and the characteristics of the organization (Imran & Kantola, 2019). The core idea of the theory underlying the holistic approach to manage change, as a result of new technology, through the belief that concentrating on change of one part of the organizational system without considering the effect of this change toward another part of the system can limit organizational effectiveness (Eason, 2014). The studies of the interaction between technology and organization also address such significant interplay between organizational change and new technology and advised firm to modify their behavior and structure as exploiting technological innovations (Colombo & Delmastro, 2002).

To address the challenges of Industry 4.0, the organization must design change by integrating all business functions instead of solely addressing a single function such as operation. The implementation of Industry 4.0 to improve sustainability in the automotive and manufacturing

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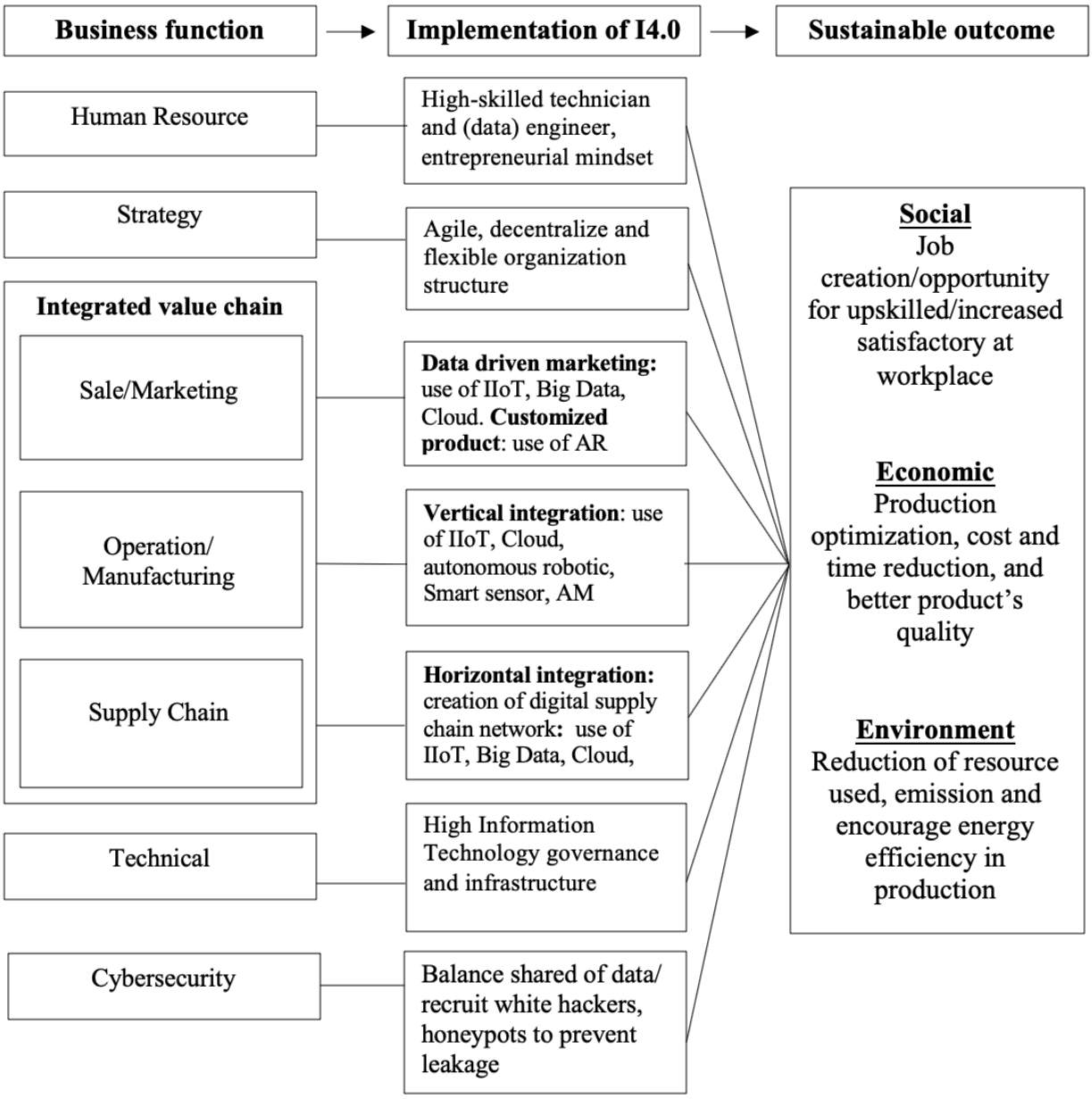
sector indicate the system change that involves the transformation of human and organization structure as engaging with new technology. This led to a major change in several business functions to successfully implementing industry 4.0. Base on the literature review, I applied the Sociotechnical System Theory as a source of theoretical concepts to design the holistic framework for the implementation of Industry 4.0 for sustainability as proposed in figure 1.

Figure 1: Holistic framework for the implementation of Industry 4.0 for sustainability



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METHODOLOGY

The objective of this thesis is to conduct an explorative study since not much empirical research has been done on the topic of Industry 4.0 implementation to improve sustainability performance in the Dutch construction industry. The application of the qualitative approach is suitable for this thesis as seeking for in-depth information that helps to answer the question of "how". Furthermore, it is widely used in the research that aims to interpret the complex, novel and contemporary phenomena, hence, appropriate for the issue of Industry 4.0 implementation (Veile, Kiel, Müller, & Voigt 2019).

Data Collection

The semi-structured interview with researcher and practitioners in the Dutch construction industry serves as a primary source of data in this thesis. As aiming to gather in-depth information, this kind of interview is appropriate for the thesis because it allows the interviewee to freely express their view in their own words, which facilitates much comprehensive information to occur (Yin, 2014). The overview of interviewees is demonstrated in table 1. In total, there were six interviewees, which three of them were practitioners from a construction company called "Dijkstra Draisma", and the rest were researcher within the building and innovative field from the Universities across the Netherlands. By observing their perspective, it gives an insight on the chance for the Dutch construction industry to implement Industry 4.0 in the future.

Table 1: Interviewee's overview

Organization	Position	Duration of Interview
Dijkstra Draisma	Chief Executive Officer	00:42:21
Dijkstra Draisma	Innovation Manager	01:03:13
Dijkstra Draisma	Software Developer	00:58:04

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HAN University of Applied Science	Researcher	00:35.12
Hogeschool Utrecht	Lecturer	01:16:00
Hogeschool Utrecht	Lecturer	00:51:23

Interview Guideline

The development of interview guideline[1] was informed by the literature related to the implementation of Industry 4.0 and divided into three sections. The first section covers the self-introduction of the interviewee such as career, job position, and profile. The second section is designed to gather information on the sustainability mission and challenges in the construction industry. The last section covered questions that aim to observe the respondent's opinions on the adoption of Industry 4.0. All respondents are provided with Industry 4.0 implementation framework (figure 1) prior to the interview. The framework aims to equip respondents with the knowledge, thereby, capable of giving an opinion on the possibility of implementation based on their experience and expertise in the construction field.

Data Analysis

Interpretative Phenomenological Analysis (IPA) is employed to analyze the transcript data in this thesis. IPA concern with examining subjective experience of the respondent. As the respondent makes sense of the phenomena, the researcher tries to make sense of the participant's perspective based on their "lived experience" (Smith, Flowers & Larkin, 2009). The interpretative engagement, hence, involves the process of sense-making and reflective practice of both the respondent and the researcher. Hence, this approach is suitable for this study as the perspective of all respondents, based on their experience in or with the construction industry, is significant to reflect the implementation of Industry 4.0 in this particular sector.

[1] Appendix 1

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For data analysis, the interview was firstly transcribed[2] and ready to be coded. The coding process was followed with several readings through the interview's transcript to search for words that are repeated to identify the preliminary code. The transcript and coding were then read through again to conceptualize the emerging theme. The emerging theme was finally clustered into a group of themes after common features in terms of meaning were identified. Following Creswell (2018), each theme is supported by the examplary of the original transcript to illustrate the participant's perspective. This illustration allows the reader to have a clearer understanding of the respondent's reaction and able to reflect on their perspectives on the implementation of Industry 4.0 in the construction industry. To enhance the validity of the research, the coding and theme were checked and re-check against the interview to ensure that they adequately and appropriately represent the essence of the respondent's experience and perspective toward Industry 4.0 implementation.

By conducting qualitative research, the advantages and disadvantages of the methodology are acknowledged in this study. The qualitative methodology allows us to gain first-hand and in-depth knowledge of the concerning issue. The interview process also underlines the flexibility that the interviewer can ask further to clarify the answer of the interviewee, which could lead to an in-depth understanding. However, the limitation is found on the difficulties to control the researcher's bias toward the implementation of Industry 4.0, especially during the interview and data analysis process. Therefore, the initial coding, theme, and finding is handed into peer, who has been appointed as a review companion to identify missing gaps and ensure the linkage of data and results (Rowley, 2012).

[2] Appendix 2

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RESULT

The empirical results based on researcher and practitioner interviews reveal several aspects of the implementation of Industry 4.0, despite the challenges, in the Dutch construction industry. Table 2 demonstrates an overview of the theme, which is underlined with an examplary of the original transcript. To implement Industry 4.0, the study indicates four major themes regarding knowledge, culture, integrated value chain, and IT that need to be developed to improve sustainability performance.

Table 2: Theme Overview

Clustered theme	Emerging theme	Exemplary of original transcript
Implementation of Industry 4.0 to improve sustainability performance		
A. Bridging the knowledge gab in Industry 4.0	Collective Learning	A1. "We have to create knowledge-based community. We have to educated people in construction to create collective knowledge about Industry 4.0." A2. "I teach people to work on the software like on the job training and organizing session to train them. I go to the station and give them an instruction so that they are able to do all kind of stuff." A3. "I think the first step is to learn what actually is the Industry 4.0 and what in it for us to make people started." A4. "They also need to ultimately educate their staff to be able to work with the new technologies. […] You constantly need to educate yourself and learn how to use them." A5: "Everyone has different way of looking at automation. The challenge is how we can integrate knowledge to have the same understanding toward this revolution"
B. Transforming the traditional culture	Adapt to Change	B1. "I think the building companies are unbelievable old school. When we talk about the production, it all about the people making crafted, which is so slow and not innovative. I think we have to urge people to embrace with new culture." B2. "We need to renovate a lot of houses in order to meet with the climate change agreements [...] If we continue with the craftsmanship way of working, there will be low productivity and the cost will be too high. I'm convinced that the whole construction industry has to move into a more industrial way of working" B3. "[…] industry is also characterized by large construction companies; they are not able to go into a transition to innovate. […] they need to be open, agile and adaptive to differences of new technology […]" B4. "We shouldn't force people to work in a way that they are not familiar with. If you change their way of working dramatically,

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		there is a chance that they will resist to those changes […] change management is a challenge to make people comfort to the changing environment."
C. Integrating the value chain	Big Data Development	C1. "I think one of the key factors to make Industry 4.0 success is that we have the data platform, where all the disconnected data are integrated across the value chain [..] The data driven will drop the price of the product so more people can afford our sustainable product and we can expand the market" C2. "[…] you can apply all the algorithm on that big data and say for example how much the energy we have used in this building" C3. "The producer will know what is going wrong with their product. With the help of big data, the producer know problem faster and that they know what should be fixed." C4. "With Industry 4.0, you can enhance the traceability of all your materials. Traceability of materials could then also help for the circularity. You can make use of this Big Data in a lot of way."
	The Application of Augmented Reality	C5. "The augmented reality we have an example that […] with an iPad, you can actually swipe to see virtual picture of your renovation […] customer can individualize their renovation and then the production can start in a few days." C6. "Augmented Reality provide virtual-reality perspective on how their new house and roof will look like, then this will also help them to make better decisions."
	Automation Enhancement	C7. "If you have very smart machines that's really efficient, maybe it will get your material flow, […] you have more control over your waste process. It a kind of lean methodology, where you can create reduction of waste in manufacturing […]" C8. "With fragmented supply chain, it obstructs us to automate them so that we can get an accurate size of raw materials, which would reduce complexity and waste from redo work." C9. "We still need AI to automate the step to transfer data from architect, which we are in process of building this"
D. Developing IT infrastructure	Data storage and security	D1. "I think you need to have a strong IT infrastructure, which is robust and scalable […] You would use google cloud or something to store the data but then you have to realize about the security and control issue because you cannot control that system. So, the company should also be concern with the data security." D2. "[…] you have to be large in term of your capital to invest especially with the ambitious to establish large factory and good IT system"

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Bridging the Knowledge Gab in Industry 4.0

One of the biggest obstacles in implementing Industry 4.0 in the Dutch construction industry is that people are lacking the knowledge of innovative technology; software and automation, and also its benefit for the construction business. This is the urgent issue that needs to be addressed as one of the practitioners suggest that to make Industry 4.0 a reality, people initially need to be educated about the benefit of this revolution (A3), and learn how to exploit the technology (A4).

To bridge the knowledge gap, particular activities is recommended at two levels. All of the practitioners perceive that training at the company level is sufficient. Each construction company is responsible to create its own on the job training program to upskilled the employee to work with new technology and innovative environment (A2, A4). However, the researcher perceives that the knowledge development activity should be implemented together at the industry level as suggesting to establish the knowledge-based community (A1). Academics and practitioners should come to discuss Industry 4.0 through this platform to build up a collective knowledge and to move forward as a whole. The knowledge-based community could practically resolve the different interpretations regarding the use of technology in Industry 4.0 (A5) within the construction industry.

Transforming the Traditional Culture

The unique culture is another challenge that the construction industry needs to tackle to transform toward Industry 4.0. The majority of Dutch construction companies have a very traditional way of working. The production process is still heavily dependent on labor resulting in time-consuming production (B1). The time-consuming production will be an obstacle for the Dutch construction industry since the Dutch Climate Act is issued to renovate a great number of houses in the Netherlands (B2). Thus, most of the interviewees have expressed their concern about this traditional way of working, which become a culture of the construction industry that limits the innovative development include Industry 4.0 revolution.

Although the Dutch construction industry mostly consists of the large company making it difficult to change and innovate. One of the researchers still recommends these companies to

learn to be more open, adaptable, and decentralize or agile to be able to catch up with disruptive innovation and stay profitable and sustainable in this digital era (B3). However, the practitioner raises concern over the emergence of people resistance to change if the construction industry embracing a new culture to transform toward Industry 4.0. Change management will become a challenge for the construction industry to make employee familiar with the innovative way of working. It is advised by the practitioner to introduce a gradual change instead of a radical one to prevent resistance and enable workers to get used to the transition that might potentially affect their working life (B4).

Integrating the Value Chain

All of the interviewees reflect the idea of Industry 4.0 implementation as a development to integrate fragmented value chain to improve economic competitiveness and environmental performance. Hence, the integration among suppliers, architecture, producers, and customers is a challenging goal to implement Industry 4.0 in the Dutch construction industry. The practitioners support this idea as the better alignment of the whole value chain can greatly eliminate mistakes that are being made on the construction site, for example, excessive use of raw material that cannot be reused. The concept of (1). Big Data, (2). Augmented Reality (AR) and (3). Automation is notified in the interviews as a means that helps facilitate this integration across the value chain.

Big Data Development

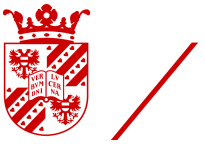
From the practitioner perspective, the construction industry can make use of Big Data to enhance economic competitiveness. Big Data can be used to integrate the fragmented information that currently cannot be used for further analysis. The benefit of Big Data platform is mainly concentrating on its ability to provide a holistic picture of the production process, which will save time in communication between functions since data will be visualized online and in real-time. They can also make use of Big Data to analyze and reduce costs in the production process, which could potentially help drop the price of expensive sustainable products. Thus, the market for this special kind of product can be further expanded (C1). Furthermore, the producers can

make predictions on the maintenance before the product breaks down, hence, offering a better and just in time after-sale service (C3).

However, the researchers are more likely to see the benefit of Big Data from the environmental perspective regarding circularity and energy consumption. Firstly, the advantage of Big Data is seen in the creation of a material passport, which encourages circularity (C4). The material passport contains information about how certain building components can be disassembled and recycled at its end life-cycle. When the buildings that are built from components with material passports are being renovated or demolished, it will be easier for the producer to track material that can be reused or recycled. The information of all materials passports is accumulated and established as Big Data that enables the traceability of each building component. Secondly, Big Data can also be applied to stimulate the energy efficiency of a product as the producer can apply the algorithms on to analyze energy usage in that building (C2).

The Application of Augmented Reality

Despite a few recorded on its practical application, the researcher insists that Augmented Reality is very beneficial for the construction industry to potentially enhance the integration between architect, producer, and customer. By observing from the building companies that already applied this innovation, its feature enables customers to make better decisions through virtual perspective experience. It also provides an opportunity for the customer to co-create and customize the building according to their preference (C6). This virtual simulation of a renovation can also lead architects to be better comprehend the customer preference of their renovation. This can reduce the mistake on the color, dimension, and excessive material used in the building. Also, this makes it easier and faster for the onsite process because the building structure such as facade will be matched with each other when being assembled. Furthermore, Augmented Reality is notified to encourage time-saving in production since the architect can send the digital scope of a renovation plan to the production platform as soon as the customer agrees upon the renovation plan (C5).



Both the researcher and practitioner reflect their expectation to apply the automation concept into the production process mainly because of the environmental benefit. The researcher recommends the practitioners to apply smart machine as it can automatically calculate the raw material used, which can limit wasted in the manufacturing process and enable circularity (C7). However, the practitioner wishes to automated the supply chain process to reduce mistakes on the dimension of ordered raw material such as woods and parts that are used in the production of insulation walls. This automation of the supply chain can reduce cost and time in re-do work or fixing parts that do not match the expectation of the producer. More importantly, this will benefit the environment because less re-do work means fewer wasteful use of raw materials. However, it is foreseen that this will be a difficult task because of the construction industry involved with several suppliers, which require time, management, and technical skill to automate them (C8). Besides, the practitioner also further expected to automate the step of transferring data from the design platform (Building Information Modelling: BIM) by the use of AI (C9). Despite the challenge in building software to sync with AI, this development will enhance the flow of information from architecture to the production platform.

Developing IT Infrastructure

The integration across the value chain requires a high performing IT infrastructure as an enabler. To achieve Industry 4.0, the construction industry needs to invest in a good IT system to enhance the connection between data, machine, and people. The researchers point out that the IT system should be scalable and standardized to cope with Big Data storage and analytic in which the company may use the Cloud. This brings about challenges for the construction industry to find a way to secure the data and information leakage since they will be stored online (D1). More importantly, IT infrastructure development requires large capital. Hence, this can be a major obstacle for a small construction business that has limited capacity in terms of capital (D2).

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DISCUSSION AND CONCLUSION

The results reveal several insights regarding the implementation of Industry 4.0 in the Dutch construction industry to improve sustainability performance. The most important similarities are discussed and compared with the current state of research by applying the Sociotechnical System Theory as it describes the system change that involves the interaction of humans, technology, and characteristic of the organization (Imran & Kantola, 2019). The result of this study demonstrates that Industry 4.0 is an opportunity for the Dutch construction sector to grow sustainably and the holistic change across business functions is required, which is complementing the recommendations advised by the Sociotechnical System Theory.

Also, the finding addresses a significant interplay between human resources and technology when implementing Industry 4.0, which aligned with the study by Hecklau, Galeitzke, & Flachs (2016) and Dutt, Natarajan, Wilsom, & Robinson (2020). The lack of knowledge on innovative technology is notified in both literature and the result as a factor that constraint the development of Industry 4.0 in the construction industry (Tay, Chuan, Chan & Alipal, 2019). The literature and result perceive human resource development in term of knowledge and skill in emerging technology to be important for the implementation of Industry 4.0. (Darbanhosseiniamirkhiz & Ismail, 2012). The result suggests the construction industry to establish on the job training program, which is complementing the study by Hecklau, Galeitzke, & Flachs (2016) that recommend management to assess the skill of existing human resource and offer training to upskill their competency instead of hiring the new one. Although, the form of learning through a knowledge-based community is not notified in the literature, however, it seems to be beneficial for sectors that are in the initial step of transformation such as the construction industry in the Netherlands.

The interaction between technology and the characteristics of the organization is also found to be significant. Both the literature and result refer to structural inertia as one of the main obstacles for the construction industry to change and innovate. Hence, it needs to eliminate this inertia force, which lies in the traditional way of working to be successfully implement Industry 4.0 (Majid, Abdullan, Yasir & Tabassum, 2011; Alaloul, Liew, Zawawi & Kennedy, 2019). As

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suggested by Kajewsk, (2002), the construction industry needs to move away from being preventive to be innovative. In the context of the Dutch construction industry, the result addresses the need for the industry to initiate change strategy to transform its characteristic toward an open, agile, and adaptive culture. This finding is complemented with the study by Veile, Kiel, Müller, & Voigt (2019) that advise the management to motivate a new culture that embraces openness to new things, and endorsement of an entrepreneurial mindset, while underlining agile and flexible organization structure. However, the result suggest that change should be introduced gradually, otherwise, people resistance to change will occur (Horvath & Szabo, 2019).

Current research on Industry 4.0 deals with technology and illustrates their capability to improve the sustainability performance of a company that already applied (Bonilla, Silva. H, Silva. M, Gonçalves, & Sacomano, 2018). The result of this thesis supports the finding of such literature because Industry 4.0 technology is expected to lead the Dutch construction company to achieve economic competitiveness and environmental sustainability. However, this requires the digitization of business functions across the value chain including supplier, operator, and sale. Both the literature and results suggest the industry to digitize the supply chain function to enhance the environmental sustainability of an industry (Müller & Voigt, 2018). This would ensure accurate information of order, which helps eliminate the excessive use of resources and transportation emission from the wrong delivery. As recommended by Glowik, Mentuccia, & Tamietti (2014), the Dutch construction industry can learn to make use of Cloud, which is applied by Renault to fulfill the technical gap in automating supply chain platforms.

To enhance economic competitiveness, the research often discusses the use of Big Data to transform the operation process into a data-driven production. The results confirm the finding regarding e.g. the application of Big Data to reduce time and cost in production (Müller, Kiel, & Voigt, 2018). Further, the use of Big Data is confirmed to increase the revenue as it enables the predictive maintenance of machines and products (Flex, 2020). Following Sequeira, Carreira, Goldschmidt, & Vorst (2014), the result also demonstrates the benefit of Big Data analysis on the environmental dimension as it can help calculate the energy saving in the production process.

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The result also disclosed the impact of Big Data to facilitate circular production as addressed on the establishment of material passports. However, the linkage between Industry 4.0 and circular production is not present in the existing study in the automotive and manufacturing industry. This leaves room for further investigation as it could have a major impact on manufacturing waste reduction.

The result indicates that Augmented Reality encourages a co-creation that enhances a better connection between architects, operation, marketing and customer that lead to increase in sale.. This benefit is convinced by Mar, (2019), which reveals that Augmented Reality offer customer opportunity to co-create with its virtual perspective feature. Both literature and result address the requirement to install this digital tool to facilitate sales/marketing and the architect to have a better understanding of the customer's requests. This would not only minimize the mistakes in the production but also maximizes the satisfaction of a customer. Last but not least, the IT infrastructure development is suggested by the result and existing study (Gilchrist, 2016) as a key success lie in the implementation of Industry 4.0. An effective IT system is required to foster a stable network and ensure real-time communication of digital tools. The result added up the issue of scalability of the IT system that the company should take into account to encourage Big Data storage. Further, concern over data security and large capital investment is addressed in both the result and literature (McGinnis, Haberman, Schmith, & Robinson, 2020)

Managerial Implication

The theoretical aspect of Industry 4.0 implementation offers a guideline for the practitioner to initiate a suitable plan to pursue sustainability opportunity from this innovative revolution. Hence, four practical strategy is recommended for the Dutch construction industry to take an initial step toward implementing Industry 4.0.

Firstly, the management should assess the skill of their worker to design an appropriate training program that matches a particular knowledge gap. The training program should include the instruction to use digital tools such as Big Data, Cloud, and Augmented Reality as it found to be very beneficial for the Dutch construction industry. On the job training, then, should be

established to make workers familiar with new technology onsite. Since there are many academics, who are interested in Industry 4.0 implementation in the Netherlands, the company should seek collaboration with them to initiate knowledge sharing to gain a better and solid understanding of the topic.

Secondly, the management should encourage workers to be more open, adaptive, and also willing to learn new things to foster an agile and entrepreneurial culture. To achieve such transformation, the management should learn to give autonomy to employees or allow the failure to happen, so that they can learn and be creative in providing a solution. The management can also appoint a change agent to make sure that this transition is operating in the smoothest way to prevent the rise of resistance.

Thirdly, the construction industry should use digital tools to integrate the value chain to pursue sustainability opportunities from Industry 4.0. To foster such integration, data exchange throughout supplier, architecture, producer, and customer and vice versa should occur. The company can start with generating Big Data integration platform within the organization to connect production, architecture, and sale. Later on, the company can learn to enhance integration outside the organization by using Cloud to foster real-time communication across suppliers. However, the supply chain function of the company will have to convince the supplier to see the benefit of this integration, otherwise, there is a possibility for them to reject this innovative means of working.

Lastly, the management is recommended to preserve large capital for an investment in a scalable and standard IT infrastructure to serve the real-time connection of data across the value chain. If renting the cloud, the management should also hire a technical staff, who is able to work on data security as transforming toward data-driven business.

Limitation and Future Research

However, the result of the study could have been more generalized if there were more interviewees from the practitioner side. This thesis is conducted to guide the Dutch Construction Industry to implement Industry 4.0. Therefore, a perspective from a practitioner should be more

evaluated in order to discuss a challenge and their expectation from this transformation. The access to the interviewee is also limited as two of the expected respondents did not reply, even though the invitation has been sent twice. Since the majority of interviewees were not fluent in English, this made it difficult to interpret the message from the interviewee. Furthermore, there is a lack of previous empirical studies on the implementation of Industry in the construction industry. This limited the foundation for understanding the problem and challenges of this particular sector that can be complemented by the concept of Industry 4.0. More importantly, the coronavirus crisis obstructed the physical investigation of the construction industry in the Netherlands since all business activities were prohibited and moved online.

It would be interesting to conduct this topic based on a quantitative method to seek statistical results to confirm the finding appeared in this thesis. As already mentioned, future research on this topic can be focused on circular production. The researcher can also investigate how the implementation of Industry 4.0 can lead companies to achieve circularity, especially in the construction industry. This can be beneficial for the sector to reduce waste that is derived from the manufacturing process.

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APPENDIX

Appendix 1: Interview guideline

Part I: Introduction

1. Could you please tell me a bit about yourself and your function at the company?

Part II: Sustainability strategy in construction company/industry

2. Can you tell me a little bit about how sustainability is important for your company/construction industry?

3. Do you feel that your company/construction industry achieves sustainability goals, any improvement?

4. Can you describe the challenges your company/construction industry faced regarding sustainability in general?

Part III: Assessment on the possibility to implement Industry 4.0 for sustainability

5. Have you heard about the concept of Industry 4.0?
    A. How do you think it relates to sustainability?
6. How desirable it is for your company; do you think it interesting to you?
    A. How do you see the benefit of it to your company?
7. How would you adopt Industry 4.0 concept and technology to cope with sustainability challenges at your company?
8. In your opinion, what challenge do you potentially foresee if implementing Industry 4.0?
9. What do you see as the best way to implement Industry 4.0 in the Dutch construction industry?

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Appendix 2: Interview Transcript

Interview 1	**Position: Innovative Manager**
	Place: Online interview
	Date: May 6th, 2020
	Time: 01:03:13 Hours

A: So, could you please tell me a bit about yourself and your functions at the company?

B: Yes! I am an Innovation Manager, and one of my tasks is to optimize the production work in the construction companies. My work involves the quality management and improvement of production line producing facade and rooftop. I also investigated the possibility to make it a mass production because right now it only fixed small-scale production lines. To do that, we found out that we have to upgrade the product, logistic, machinery, digital platform. So about four or five themes we had to upgrade and make it better, which is quite a challenge. So yeah, that's what I do.

A: Ok, so how long have you been working in this company?

B: I've been working at this company now for six years.

A: Ok. All right. So, we go to question in section two. It's about the company's sustainability strategy. Can you tell me a little bit about how sustainability is important for your company?

B: I think if you look at sustainability for our company, it's our DNA.

A: How is it?

B: It's important to everything we do. If you look at the product, there are two types of products. One is designed by the client, which we cannot do anything much about sustainability. Another type of the product is designed by us and sustainability is valued in this kind of product. For example, we always have products like houses. If we design the houses and if we make a retrofit process or something like that, it's always without gas. We look at materials, whether they are natural or not. So, from the start of design, we look at all factors including source material, energy, embedded energy, CO2 footprint. Everything is within the

design process.

A: Ok, so when you pick up the natural materials so you have your own supply right. Where you sourced all the wood and everything?

B: Well, we have our supplier, a basic supplier of wood that has all sustainability certificates that we need. What we also do is we are working with our R&D center. We do a lot of experiments with materials that are not normal in the construction sector and see if it's possible to extract the plant and put it in the construction sector for insulation or for stuff like that. You can see the plants and seeds are now experimenting on for an alternative of insulation that's now made by fossil fuels. This is a fully biological way of insulation. We don't know yet if it's going to work. R&D trying it but we do think like that. If we have a source like this plant and we have a product like our facade, then always the question at the beginning, if we start the project, is it possible to have the source scalable and payable for our production facility? otherwise we don't start with it because we don't want to have a niche market, we want to have a mass market.

A: Ok. Do you think that you guys have another sustainability goal except for producing a sustainable product?

B: Well, just. Yeah. We have a Corporate Social Responsibility program. We were the first construction company in the Netherlands that had the score on that one. That means that we look at everything, energy saving and sourcing material, and the way of transportation has to be cleaner. Last year, we ordered 10 electrical passes and the car is in our pool right now. So, energy savings in the offices, paperless working. You name it. It's in our system. We have to report on that once every year in our annual report or finance. So, yes, sustainability is part of our company' DNA.

A: Ok. Right. So. OK. For you, a sustainability goal, you have like two major things, one is your product that has to be in sustainable design that compose of sustainable materials. And then you have your CSR, corporate social responsibility strategy on energy saving, in your office to do a paperless. And then you also have clean transportation. Do you feel that your company has achieved sustainability goals, any improvement?

B: It does not start from zero to 100 percent in one year. It is a process that we're working on. We are also trying to get rid of the chemical component in the built environment. So, the first

question is, can we get rid of it? If the answer is yes, we will get it out but if it's a no, the question will be can we develop alternative material ourselves? It is a bit challenging.

A: But you're working on it, right, to get rid of the chemical.

B: Yeah. So, every project is working on making it cheaper, more feasible for production, and more sustainable.

A: Ok. I feel like your company is in the process of being more sustainable. So how do you feel that your company has achieved some of the sustainability goals? Do you see any improvement from time to time or is it steadily developing?

B: Both! We have been awarded with the most sustainable construction company. We have a King William award and sustainability is a very important part of the award. So, yeah, we have. We've come from far. And we are one of the most sustainable construction companies in the Netherlands. So, we had very big steps. Only, as always, we still have to develop products to be more sustainable. And that is the hardest one! And you have to develop quite a lot of that part. This is because you run to the boundaries of your product line and at this point, we cannot make a big step anymore. A step we can make is to study the chosen steps, every next step is a step with quite a lot of impacts on money, on time, and resources of the company.

A: Ok. So, the big step is for reducing resource use or creating time-saving in production or something like that.

B: The biggest step right now is to make time-saving into production on the same production facility, more product in the same production line. That is flexibility.

A: OK. So, you say that in the product development, you also allow your client to design their own product, right?

B: Within boundaries, yes.

A: Ok. So how does that work? You let them choose the materials, the colors and everything?

B: Yes, at this point, people can choose quite a lot. They can choose what kind of insulation they want to have inside the facade and choose the tiles and color. They can choose the for new buildings, the whole design of the floor. So, they can choose pretty much anything that they have options. However, a lot of changes do mean a lot of labor efforts wherever it means costs. Cost means fewer interesting products. So, it's a quite difficult balance. But if you have a house and you have a lot of options for houses, that can work. But changing the production

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facility from facade for houses to facade for utility buildings. Oh, that's a very expensive one but that is a flexibility we want to introduce.

A: All right. So. Ok. So, your customer can choose something but not everything. So, like the basic features and things like that.

B: I mean we know that people want to have more choices every day. This is a hard balance. More choices mean more programming, more types of machine production facility.

A: All right. Your company has their own sustainability goals. Can you describe to me the challenge that you face regarding sustainability in general?

B: Acceptation by people,

A: How?

B: If You go from a car on petrol to a car electrical, you have a totally different way of fueling the car. If you go from a house, from a natural gas source to a house, from a heat pump, you have a low temperature system instead of a high temperature system. And that means that you have another kind of house and your experience you have at your houses is different. So people think it's hard to do it. That's one. The second one is costing money. You have to invest in sustainability. A lot of people don't have the money upfront. Our product is not in a trend like Apple's iPhone. Our product is something that will show outcome in the future. For example, if we tell that the gas will be forbidden in the future, some people might be interested in it, but not a lot until the law is in place.

A: So, you say that people will have to be forced to buy sustainable products?

B: Yeah. And if you look at sustainability in the construction sector, our products don't have the impact right now unlike gadgets. Now if your house is 20 degrees. It will stay 20 degrees. Your house has a heat source. It will have a heat source in the future not from gas but from electricity. People will have the same experience regarding their building. There is no joint factor you can give people because what they have now, they will still have it in the future. So, it is hard to sell a product that people need to have for a future, for sustainability, they don't have an effect right now. The effect is in years or maybe in centuries. So, if the effect is that long, people wouldn't spend money on that.

A: So, it is about sustainability awareness among the consumer, right?

B: Right, and the product is still expensive. The design platform has to be more flexible but we

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still find the way to do that. The house is in a variety form, it does not like the car that they all look the same. Especially in the Netherlands, every house is different according to distinct preferences of people. So, the price is a major concern for us. We want to learn from the car industry because in history it was very expensive but now, they can produce it in a much cheaper way. The innovation must make it happen for them. But for the construction sector, we do it in an old-fashioned way right now, the interesting question for us is how do we step out.

A: So, you saying that your product is kind of expensive, so right now are there any customers who can afford it?

B: Yes! There are some customers who can afford it right now for example, the building company. There are companies that take a long vision. However, our market is quite small so we want to expand it.

A: So, right now you have a niche market?

B: Yes! If we can put down the cost a little bit and you can put in more flexibility, the market can be expanding because there are 4 million houses in the Netherlands but we still don't know how to get there

A: Ok! So now we are going to the last section of an interview. It will be about your opinion on the implementation of Industry 4.0. So, have you heard about Industry 4.0 and how do you perceive it?

B: Yes! I heard a year ago. I only see it in line of car production. For me right now it's a little bit like magic. If you have enough data and money, you can do everything with that. For me it's like you buy new software, it can do everything you want but I don't know how exactly.

A: So, you only know that it applies in car production and it also involves high technology. So, based on your perception, how do you think it relates to sustainability?

B: The data driven design platform will make a design more individual, production process more efficient. It will drop the price of the product so more people can afford our sustainable product. The market will be bigger. The DNA of the product is created to save energy and façade to capture Co2. If people purchase our product more, it will lead us to sustainability goals. This is an indirect way how it affects sustainability.

A: You mentioned about big data/data-driven design, what technology do you think should be added to make such a big data?

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B: I think the whole data structure is not in the construction industry yet. If we look at the car industry, they have the data platform that runs the machine, and the machine is used to run the design. But what we have right now in the construction industry is pieces of data collecting from proper data based but we don't know about the quality of the data and its connection. I think one of the key factors to make Industry 4.0 success is that we have the data platform, where all the data are integrated.

A: So right now, how do you collect the data from people communicating?

B: In the design process, we collect data with drones and send it to the engineer to make a design. At this point, we get a data set and people are connecting the data set and send it to action. Also, data goes into the machine, people communicating if they are going right or wrong. So, it takes time and depends on people's opinion.

A: In your opinion, what challenges do you potentially foresee if implementing Industry 4.0 in the construction industry.

B: The challenge of being the first one. There is no blueprint for us and we have to find out everything ourselves. We have to find a way to understand the technical part of Industry 4.0 for example the Big Data. We are making the bit and the bite to communicate with people, consultants, car companies, which not really in a holistic way. It's probably a mess. Also, the suppliers of the machine in our company are various, so it is challenging to make the data as one. I think the most challenging task for us is to learn to create the data platform across the value chain, where everybody can access it whenever and wherever to make people work together.

A: So, it's like making the horizontal integration, connecting producer, supplier and customer?

B: Yes! I think that the right word. Let's say if the customer selects the product based on their preference, the data go into the producer and to the right machine to produce the ordered product. It should also include the integration of machinery. It's like the whole process is integrated from high level to the lower level.

A: I think that is a challenge on the technical product. Now, do you see the challenges in the management point of view?

B: Education for people has to take place. For example, if we have a machine and people working on the façade, and the machine is telling him to put material into the machine. People

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are not used to listening to the machine.

A: What do you see as the best way to implement Industry 4.0 in the Dutch construction industry?

B: I think the first step is to learn what actually is Industry 4.0 and what is in it for us to make people start. And then if it is beneficial, we would let people know how it is beneficial to the construction industry and find a way to implement it together step by step.

Interview 2	**Position: Researcher**
	Place: Online Interview
	Date: May 8th, 2020
	Time: 00:35:12 Minutes

A: Can you tell me a bit about yourself?

B: So, I have a background in chemistry and material science. I started to work for main companies. Always innovation. And I Walton was a company producing and developing copiers, some printers. And the next one was a company developing and producing boilers for central heating systems. And I worked for quite a while for Philips. Partly in the consumer products and partly in professional lighting. The longest part of my career has been an R&D manager. So managing a team of developers, of different disciplines, developing products. And I was also involved in strategy building with my company. So, what kind of opportunity was seen? Which areas should be developed? Which products are needed whenever needed? That was my function. Since one and a half two year, I changed the scope and I am now partly working for the HAN University of Applied Sciences. As a researcher in lean product development, and partly as a consultant for my company. I opened my own company where I helped other companies to speed up their innovation. So, innovation is the keyword in my career.

A: That's great, it's very interesting. So how are you familiar with Industry 4.0?

B: Well, I've had in my career, I've developed products and of course, these particles had to be

produced. Scorable was in contact with manufacturing. It depends on which company you work for. For instance, Philips Consumer Products is mass manufacturing, a low variety product. Their production is fully balanced, sometimes even on the second and third, and made as efficient as possible. If you work for service lighting, the product variety is huge and the quantities per order are lower for their production. And that's a bit more related to the Industry 4.0 concept like this. So, it depends. I did both.

A: Okay. Thank you for your introduction. It's very impressive like you have a lot of experience in production and manufacturing.

B: I also join a research about Industry 4.0 on organizational aspects, but also on technology aspects like Augmented Reality. One of the questions, for instance, could AR be beneficial for people who have difficulty in working, people who have a mentally problem that cannot learn that fast and work longer in the company?

A: So, it is about the AR and how it works. We are now going to question in a second part. So can you tell me a little bit about how sustainability is important for the construction industry in the Netherlands based on your experiences?

B: I'm involved now in the big projects, where also Dijkstra Draisma is participating in the project called future factory. So, from that knowledge, which started somewhere in January, I have learned a little bit about the construction industry. What I've learned so far is that the construction industry is quite a traditional industry. They're working a lot with craftsmanship. Every building, every house they produce, they make it tailored. They're not really used to working in an industrial way. Now, the experience that I have on producing vacuum cleaners or producing light fixtures experience is from industrial applications is not really experience is used in the construction industry. But I'm absolutely convinced they need it. In the Netherlands, we have a huge challenge. We need to renovate a lot of houses in order to meet with the climate change agreements. And also, we need to build a lot of new houses to accommodate for all the people who need a house. If we continue with the current way of working with a more craftsmanship way of working individually solving issues, then the quantities that become built are simply not high enough. Also, the cost will be too high. So, I'm convinced that the whole construction industry has to move into a more industrial way of building.

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A: Can you tell me a bit about what do you mean by industrial way of making product

B: Well, it's a way of making just like Dijkstra Draisma is already doing a bit by producing in a factory. Partsthat can be produced in a factory and then the assembly almost put old wooden houses, minimize that as much as possible, and also prepare as much as possible. So, if you prepare the parts of the house, also integrate electricity, water, every utility that you need, try to integrate it already in the process to manufacture in your house. That's what I mean in this industrial way. If you do this, you can optimize your factory with these techniques and this is what was developed in the production industry and industrial industry. You can use lean techniques. You can use smart manufacturing.

A: Ok. So, it like minimize the on-site process. Right?

B: Yes, minimize on-site building and also minimize the corrections that you have to do on-site. Prepare as much as possible, but also your quality goes up and your rework goes down. It's also a bit more standardized and as a consequence, it also means lower labour cost.

A: Yeah. Because I heard some Folkert though their companies are heavily dependent on labour and that is time consuming and the product is not really standardized. So you say that the industry, the construction industry, for example, Dijkstra Draisma, are heavily dependent on labor. And it is time consuming. It is not really cheap and it does not imply the standardize of the product. So, you suggest that they would minimize the on-site process by prepare the finished goods in their manufacturing so that they can optimize production line and that it will be cost-saving.

B: Right!

A: So right now, from your point of view, how do you think sustainability is important for the construction industry in general?

B: In general, in the Netherlands, we need to achieve sustainability goals. That means that we have to reduce the energy that is needed to live in a house, to warm up the house, to have comfort in the climates, to have warm water, to shower. It means a lot of houses need to be renovated. And if you have a new house that you already take into consideration.

What I've seen from the Dijkstra Draisma is that they are already trying to prepare for this renovation and to do it in an efficient way with higher quantities, by using some of the industrial techniques.

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A: Are they already producing some stuff in the factory and that way they are helping with sustainability goals?

B: What I've seen is that the new buildings today, the renovation that they do, they take care of insulation to limit the energy usage. And they're also thinking of the technical insulation that is needed to do the job very efficiently. Energy efficient way, they are at least trying. Probably, we can become better with this new technique. It needs better insulation. But I do see today that they have ambition to be such a company.

A: Okay. So, we are going to the last section of the questions. You will be asked about your opinions on the implementation of Industry 4.0. So, have you heard about the concept of Industry 4.0 or if so, how do you perceive the concept of Industry 4.0?

B: I've definitely read about the concept of Industry 4.0 and I find it a very good concept. Well, it combines new technologies to produce in a better way and the more efficient way. It's also combines new technologies to allow people to work in a more pleasant way and keep people who have a bit of a handicap for working to keep them working longer to also give them a job and it contributes to our environment, try to limit to the climate change. I also see a link toward to circular economy. I'm not sure if it is part of your research. But if you go for a circular economy, then you also need these technologies to make that happen.

A: Can you give me some examples of how particular technologies Industry 4.0 may lead to circular economy?

B: Well, in one part of circular economies that you try to produce more locally and then you only produce the things that you need. So that limits mass production and houses production of specific needs will not achieve like additive manufacturing is very useful. For instance, if you have a product, if a part is broken, the current Linear model will tell you to either throw away your product or to have a new part, which is produced probably in China or Asia shipped by boat come to the Netherlands and then you will repair it. With new technology, you can perhaps go to a printing shop in your local city having them made and then repair it. It saves the fuel of the boat. It saves the costs of manufacturing. So, it's quite a different economic model. We're not there yet by far. Not at all. But the new technologies will help going into that direction.

A: Ok. So, you say that additive manufacturing will help create the mass customization? That's

right.

B: Yes, it will help mass customization. Right! One other aspect. If I may, all the aspects of circular economy, if you go from buying products to offering service so that you are not buying a product anymore. But if you get the service, you are not buying lamp by having the lights on your desk but buying a service that needs data. If you find it, there's a company you need to understand the lighting conditions, and how long it has been taken. What do you need to repair it proactively? And data management and big data is also part of Industry 4.0. You have to already design it in your product, but you add sensors so that you can know how the product is doing and you can be proactive.

A: So you do think about after-sale service. The producer will know what is going wrong with their product. With the help of big data, the producer knows the problem faster and that they know what should be fixed.

B: Indeed. Even before the customer notices it that the product is doing its performance less. The producer of that part already knows, hey, this is going in the wrong direction. If we wait for a month or two months, then it could break. So better now already repaired.

A: Yeah. Yeah. That's really smart.

B: It's already done.

A: Oh really. In which way?

B: With some smart machines that you can, for instance, if your part broke out the machine needs a little bit more energy or they get warmer in operation. And if you measure its temperature or you measured a current that you need to rotate. You see, there is a change in the normal consumption. You can already go there and say we need to change the ball bearings. It's not futuristic. It's really happening but we can do more.

A: So, like, it's happening in like air conditioning or something like that. Like smart electricity.

B: Yes, you can do that then. If you convert into a construction industry in a house. If we could add more sensors in the house. Temperature on carbon dioxide or carbon monoxide or dust particles or using that data, you can optimize your internal climate by steering to the technical insulation. We need more ventilation or we need more temperature or we need that part of it to give the inhabitants the possibility to monitor water to to adjust to their preferences to the user interface. The user interface needs the data. That's also part of this concept. I think it's also

related to Industry 4.0. And if you don't think further, if your ventilation system is wearing out so it might lose its functionality, then you can proactively say we need to change the fan. We need to change some electronics, a heat pump or whatever. Also, I see a link between Industry 4.0 and eventually a more circular economy.

A: Ok, so especially in the context of the construction industry, you suggested that if they can add more sensors, for example, in the insulation wall, that would be a smarter way to deal with those building components that will solve the climate change problem.

B: It also helps going into a different economic model. If you are now the owner of a house of an older house in the Netherlands, you need to renovate it to make it more energy efficient. That is costing you a lot of money. And not only building owners have that money. They think they could try to rent money and pay from their mortgage or the money they have. But you can also offer them the product or the solution as a service. If you continue to pay the same amount of money that you currently pay on energy. If you paid it to us, the company provided during the renovation, well, then perhaps you can also pay for it without them having to pay instantly. A lot of money is paid every month.

A: If they are applying the concept of Industry 4.0 in their production, do you think how they would reduce the price of these smart products that will happen in the future?

B: I think it will be reduced significantly to 20, 30 percent or 40 percent.

A: By the use of robots, Big data, smart machines...?

B: Yes! And producing in an industrial way with larger volumes, with less rework, less quality issue. I think you can reduce a lot. Also, a better organization, more lean way of working

A: So now what challenge do you potentially foresee as implementing Industry 4.0 in the construction industry? Like for now, you've said that construction industries and airlines are kind of heavily dependent on labor and it's also not really operating in a smart way. So if they are going to develop into Industry 4.0, what do you think it will be their challenge that they are going to face?

B: The biggest challenges. It is a very disruptive change. A lot of companies might not be able to take a change and might disappear. Some auto companies might be able to take a change and gain the market share. So, it's really a complete change of the setup. Now, how was the pilot produced to have small companies who do only part of the roof, like the insulation work

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or the companies are doing the profits? That might not be needed anymore. Or to a much lesser extent, because it's done in the factory, the Mason people have to put the bricks together with mortar. They might not be needed because it's already done at the factory. Now, that's a huge change. It might also lead to unemployment of some of the people in industry or they need to be retrained in order to fit in those in the new situation to become factory workers. I don't think it's easy. If I may add what I just said, if you increase productivity significantly. Well, I would say 40 percent. This means that you need less people. That's also a social issue that we need to solve.

A: So, do you think that the company would find balanced ways of giving them more education on mechanisms or technology and enable them to like work with technology so that they don't have to be laid off? Do you think that's possible?

B: Well, it's a tough job, but it's possible. It's also inevitable. They have to do it. Well, just like the machine building industry, they also need to ultimately educate their staff to be able to work with the new technologies. Knowledge is going so fast. You constantly need to educate yourself and learn how to use them. You cannot stand still. It will also happen in the construction industry.

A: Ok, do you have anything to add? Do you see any challenges for the construction industry to implement Industry 4.0 apart from the workers point of view?

B: Well, also a consumer point of view. I don't know for other countries, but in the Netherlands, people are used to designing their own specific house with exactly how they wanted it. And it makes it more difficult to produce in Industrial 4.0 Way. So, we also, as a customer, might need to change our habits and learn to choose from buildings that are produced in such a way.

A: You mean is it in a sustainable way?

B: This one. And secondly, currently we can design almost everything that we want. A house with a specific architecture. Yeah, there's only one house in the Netherlands that accepts architecture. This might not be possible anymore. So, we also need to limit our needs to distinguish ourselves and our building. It might be less variety.

A: But then for Industry 4.0 is also enabling customers to co-create, to customize their product to write their own colors or something like that based on the car industry. Right. So, what do

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you mean by the customer will be able to choose less varieties of the product?

B: Well, the variety that you implement with Industry 4.0 is just based on standard building blocks, based on the modular architecture. So, you have some standards with standardized interfaces like Lego blocks. And then you can build different things, but they are still the Lego blocks. And if you want something that cannot be built from Lego, then you have to also be a little bit more modest in your wishes. If you use a model of building blocks, variety, you are still absolutely possible. You can have different designs, but not everything is possible. If you will, a gold roof. I don't think someone with a loaf of bread is only a king or a queen. Yeah, but that's not a standard house.

A: Last question, what do you think is the best way for the construction industry to implement Industry 4.0?

B: We have to start like we are doing now with Dijkstra Draisma. We have to build some showcases that it does work. I expected a more gradual change. To build confidence with consumers that they will have a very nice house.

Interview 3	**Position: CEO**
	Place: Online Interview
	Date: May 8th, 2020
	Time: 00:42:21 mins

A: Are you ready for the interview?

B: I didn't prepare myself much for the interview because it was quite busy.

A: Yeah. OK, yeah. It's just based on your opinions about what you will be asking. So, first, let me introduce myself. My name is Natnicha. So, you can call me Nice. That's my nickname. And I am currently studying sustainable entrepreneurship at the University of Groningen. And I'm doing a project with your company in contacting Folkert in the projects of Industry 4.0 in

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the Dutch construction industry.

B: I hope you have heard a lot already from Folkert

A: Yes! And I kind of like to know your organizations are developing to address smart factories to improve the productivity and sustainability performance. So, I study on the topic of how the Dutch construction industry can adopt Industry 4.0 to improve sustainability performance and your organisation is the case studies of my thesis.

B: All right!

A: So, the interview will be divided into three sections. The first will be about your introduction. So, you know, just introduce yourself. And the second part will be about your company's sustainability strategy. And the last action will be about your opinions on implementation of Industry 4.0 for the Dutch construction industry. So, OK, let's begin. So, could you please tell me a bit about yourself and your function at the company?

B: Yes, my name is Biense. I'm 51 years old, married with two children. Maybe it's interesting. And I am the son of a building constructed in the north.Im a single owner of the company. We have around 200 million turnovers in a year and we work with 350 full time employees working for us.

A: So, your job is like the owner of the company, so is like a managing director, right?

B: Yes! And We have a team, a CFO, product, the board of a company mainly responsible for production. And we have one guy mainly responsible for business development

A: So, do you consider your company as a small to medium business?

B: We're. I don't know exactly. I should do some figures, but this year we almost had the 200 million turnovers. I think we're in the top twenty-five SME in the Netherlands.

A: Ok, thank you for your introduction. Let's go to the second part. I heard that your companies are doing a lot of sustainable building and smart products to cope with climate change, so can you tell me a little bit about how sustainability is important for your company?

B: It's very important. In the old time, the construction works were only measured by an architectural development. The customer wants to build a cheap house so the contractor does not include sustainability in the building purpose. The price is the condition for the consumer. And we wanted to lose that old view. We have to be more value to your products. We supply building the community and those buildings have to be sustainable. Most of the time they have

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to produce energy instead of use energy and it has to be circular. That's why we have a different strategy because sustainable is key for us. So, our building has to be sustainable. It has to be able to produce energy, not using energy. So, we have to be more responsible for what we build not for one year but over times.

B: 80 percent of the time the customer had trouble with building whether with temperature or fresh air. They don't take responsibility themselves; they call advisor, architect and advisor. So, our company wants to address this gap to take responsibility in what we build. We want to give them a guarantee for 10, 15 or 20 years for the energy at your home or your building. This is the change of us instead of the rest of the building companies in Holland. There are only a few who are always on the same road with us.

A: Oh, OK. So, your products are kind of like producing energy, not using energy. And it seemed that you are involved in an energy transition building, right?

B: Yes! We think the sustainability goals of the government is the good chance of our companies to get a new future, to take responsibility and to make products which accommodates the governments for their goals.

A: Can you give me examples of some of your products that produce energy, not using the energy that you mentioned?

B: We have buildings in Leeuwarden that use green gas from the waste plant behind the building and use it for giving energy to make heat. The social house that we build also uses energy from the biogas. We also sell solar panels to produce that energy in the building.

A: OK now you've talked about your sustainability goals and objectives at your company, so do you feel that your company has achieved the sustainability goals or any improvement that you wanted to achieve?

B: Yeah, what would we produce in our factories is of high standard at this moment but we want to do it better than we did. We need courage to go further. We think we always have to invest, always change the theme. We have 32 new innovations running and we think we can use them to win the enemy. The new factory we are designing is all based on moving into the next, not being satisfied with what we achieve already.

A: So, like you wanted to go more for more sustainable housing in terms of quality and energy saving on the product.

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B: And also, my direction with my board. I tell my colleague they can say no to the customer if they don't want our product anymore. We not always please customers if they do not want a sustainability-based product. This is because our goal is for sustainability, if the customer doesn't want it, they can choose another company. Sustainability is our minimum standard otherwise we aren't heading to a good future. I need to explain a lot of my direction because they're not used to this.

A: It's about the topic of building awareness on sustainability for the customer, right? So that will be a challenge to you. Right?

B: Yes Of course. There always will be a challenge!

A: I want to know, like customers these days, how they wanted to consume the building materials. Like you say that not the majority of the customers are willing to adapt to sustainability, so what kind of product are they currently purchasing?

B: If sustainability costs money, then they would say nahhh. If we tell them you will be earning back from purchasing this product, they might be more interested but they will ask how long it will be earning back. We say in 15 years or something. So, only a few of them are willing to invest in sustainability. People believe in short term, not revenues five to seven years.

A: Yeah. But then in the future they will have to change because of the climate change act, right? Every building has to be renovated into an energy transition building and they will be forced to choose a sustainable product.

B: If the governments do not put the norm high enough. People are not very interested in sustainable products. Our competitors are not ambitious enough, so there will be no competitiveness on sustainable products in the market. The government has to put the bar higher so the company will be confident to compete for sustainable products.

A: Yeah. So, do you think a cheaper product might be another challenge to your company, right. Because a sustainable product or smart product is kind of expensive so that is why people do not really purchase it until they are forced to.

B: The nice thing would be because social housing, that is 2.5 million houses are owned by the social housing companies. They have to be sustainable.

A: If the government forced people to renovate their house to be more sustainable, maybe they

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would launch the subsidy program too, to help people to purchase or afford that kind of innovative or smart product.

B: If you're smart, you start with the social housing company and then you get a lot of experience, then you can go into it. That was one model.

A: Do you think that developing or improving your production line might be an alternative way to lower the cost of your product?

B: Yes, I think so, but for lowering your price you need a workflow. The workflow is more important for critical mass like the car industry has. So, we need a good workflow to minimize the production cost. And the Netherlands is a free country, people are also free to choose their own design of house. For example, the ceiling has to be 2.60 meter but if you go to another community, you will see another type of building with different standards. If you go to America, Germany, England, they are the same and regulated. So, to make it standardize, it is so difficult unlike the car.

A: So, it's like each community has their own preference of building so that you can't get a mutual preference of people and bring to the production line so that you can't start a mass production.

B: Yes, exactly!

A: We go to the last section to get your opinions on the possibility to implement Industry 4.0 in the Dutch construction industry in general. So, have you heard the concept of Industry 4.0? Or how do you perceive it?

B: I think it's what we're doing with a future factory and it is mainly based on subsidies or renovation. What I think this should be is also a matter for building new houses, a new building but not renovating. It is because renovating is still quite hard. It is a high social challenge and also a technical one. The new one is really easy to build. So, we have the knowledge. Why don't we do it? So, in Factory 4.0, the higher standard of the product should be the norm.

A: So, for you, the future factory will produce a higher standard of the product and also increase your productivity to serve the government policy that will force people to renovate their house to cope with climate change. So, for you, it's kind of linked to the economic point of view, right? Because it would improve the quality of products and also increase the numbers

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of products that you can produce, right?

B: Yes, labor is a problem every day. People are not more interested in going into the building industry. They are going to other industries. We lose our personnel. If we have no personal, we can industrialize and robotize the factory.

A: Do you think that Industry 4.0 would save a resource or it could decrease waste in the production line or something like that?

B: Yes, if we do it in a real circular. we can reduce waste. We need to address recycling circularity. And I think Industry 4.0 has to be circular also.

A: So, your expectation from the future factory would be a more circularity of your business model. So, you're using the waste from production to produce a new product, for example,

B: Yes! keeping ownership with yourself and component with yourself. We rent the building for 40-50 years and then we take it back and reuse the design, component and re-sale it to the market. So, it is all about the reuse.

A: Okay, so re-using the old one.

B: Yes! designing it now and reuse it in 30-40 years.

A: That's really smart. So, I will repeat your answer. You see the benefits of building a future factory for economic competitiveness and also for creating a circularity of your product, right?

B: Right!

A: So, imagine that your company achieves the future factory right now, how would you adopt industrial 4.0 concepts or a technology to cope with the sustainability challenge at your company?

B: Putting it on our design team, putting it on our core element. Putting the knowledge, which has to be in developing of our development goal

A: So, it's like make your employee engage in this development, right?

B: Yes! We have to make them a part of the solution. They have a lot of knowledge; they have to be in a team to reach our goal

A: Do you think that your customer can co-create their product if you have a smart factory?

B: Yes! They can make their own decision on a laptop. They have the choice to choose their sustainable product. They are designing it themselves. They put it all together.

A: Okay so they will have more opportunity to choose for themselves. As you mentioned that

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you want to take care of what you build, what do you think about the after-sale process with Industry 4.0 concept or technologies like Big Data or Sensor on the wall?

B: Big Data is our goal. We can develop so much from that.

A: Alright! In your opinion, what challenges do you potentially foresee if you go into Industry 4.0?

B: There are a lot of challenges for our company. We don't know exactly Industry 4.0 at this moment. I have seen that other industries use drones to inspect the on-site process and it is all data driven. So, I think we need more servers to do that. We have expectations of Big Data, but it is much more difficult than we thought. So, we have to learn a lot on a technical issue especially when needing to transform into a data driven business.

A: What do you see as the best way to implement Industry 4.0 in the Dutch construction Industry?

B: The Dutch construction industry is old school. Once I tell our neighbor company to industrialize the industry If we want to reduce the CO2 and cope with the climate change act. They do not believe in it, because they are producing in the old school way. I think 5% of them know exactly what it is but 95% are not interested in changing. So, I think the building company is an unbelievable old production. When we talk about the production, it is all about the people making the product. I think we have to educate or urge people to change. In university, the study book that students used is a book that we used 50 years ago. That's a problem, the school does not equip with the new way or industrialize the construction work.

A: So you think that the construction has to embrace an entrepreneurial culture like being adaptive and open to new things, right?

B: Yes!

A: Ok that was the interview question, thank you for your time for the

Interview 4	**Position: Lecturer**
	Place: Online Interview
	Date: May 13th, 2020

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	Time: 01:16:00 hours

A: Can you describe a little bit about yourself?

B: Yes! I have an architect background. I like innovation and change and I like to work in an environment that endorses that. I am now a teacher at Hogeschool Utrecht, a University of Applied Science in Utrecht. I taught people to ask the question why because as you always do the thing that they used to, there would not be a change. I always urge my students to be innovated. I specialize in energy transition in the building sector and innovative product development especially the façade. I am part of the research group in our University in new energy in the city.

A: Ok so we go into a second part of the question, how sustainability is important for the Dutch construction industry?

B: Sustainability is important for the construction industry. This is because of the climate change act that was created by the government. So, the innovation will be important like what Dijkstra Draisma is doing. The sustainable housing is on the agenda to achieve the circular economy and energy transition. In the future, the construction industry may develop toward circular economy by incorporating 10 R model, for example reduce, reuse, recycling and so on. A more flexible product should also be addressed that is easy to maintain and connect with customer.

A: So broadly the Dutch construction companies are trying to go for more sustainable products by developing energy transitions kind of products and if they can they would go to the circular economy to reduce reuse or something like that.

B: The circular economy has also done as a service model so it's related.

A: All right. So, what do you mean by the service model?

B: The service model is that you are not paying for the products for the service. If you give me a toothbrush, I'm not paying you for a toothbrush, but for the amount of time I can brush my teeth.

A: Okay. From your experience or from your perspective, do you feel that right now the construction companies in the Netherlands are achieving sustainability goals or do you suggest any improvement?

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B: Maybe I'm a bit skeptical about that. They are now developing products for typical housing stock in very plain forms and not that difficult. Yeah, and well, there's a lot to renovate that is more difficult. So there should be more flexibility in the systems that I know and there comes Industry 4.0 in my point of view that you create more complex, more flexible products that can be configured on different housing types and subtypes. I'm not sure if you know this about the housing standard in Hollands, its forms are and how its typology works.

A: Well a bit.

B: Well then, I think you can see it all around also in Thailand, I guess. Yeah, that's buildings look the same but they are different. This complexity is very interesting. Also, the customer demands what they want, what they like to have, we should create products that connect to that demand.

A: But then I heard that some of the problems are that the customers don't really want sustainable products because they don't know what it is and that is really kind of expensive if you purchase that kind of smart product to save energy or something. So, the customer is not really willing to pay for it, right?

B: Yeah, but there comes a different business model that we should look for because actually what they want is a good and healthy comfortable and safe home. It’s all about connecting to the needs of the customer and actually reduce cost in that way and do the initial investments yourself and create a service model. I think that's upcoming. I think that's very interesting.

A: All right, so based on your experience. So, do you see any challenges that the construction company are facing regarding sustainability?

B: Yes, the construction projects are context dependent. Hmm. We have very basic trees and streets neighbors. That guard is always in a different variable mental context that is every time difference and this means that you have some extra labor. Also, if you do it's very specific and reduce the labor as much as possible if always a different way of dealing with them and with the houses. What's different in the construction industry is that these are products that will be functioning for 50 years to 60 years. There are not a lot of other products or things that have that same scope, maybe in civil engineering like in the road’s buildings. In the construction industry, we have a lot of labor on-site. That's a major thing. There is a lot of manual manufacturing indoors.

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A: Yeah, so it seems like the challenge is revolving around manual production, right?

B: Yes, there are changes going on, but because there is no better products approach. Yeah, it's always an architect's work that we combine different configurations and especially on material and component level. And then you have a lot of labor in it because you have to do it on-site and that make labor intensive.

A: Yeah. Do you see any challenges from an environmental point of view like in their production process?

B: Yes. It is. We have a lot of waste, energy waste as well and I think the challenges are more on a cultural side. We do things all over again, and it's not feasible to develop the product portfolios that they internalize and configure it on the different building types. I think that's the major barrier in the developments in the reduction of waste. Then we create a lot of waste because we have a unique culture of not getting change.

A: Now we go to the last section of the interview. This will be about the industry 4.0. So, have you heard about the concept of Industry 4.0 or how do you perceive it?

B: Yes, I have heard of it. I actually do a MOOCT, massive open online course of NX. They have the University of Hong Kong course about industry 4.0. That's what I used because we can see a lot of examples in the construction industry. I need to get another source to understand about it. What I find is also a major barrier in depth in that sense. There's a lot of ICT, Artificial Intelligent kind of way to go. To create that, you have to have a company that's 70% IT specialists in service. And those people are very hard to find and the construction industry is not very sexy in that sense. So, there's a sort of challenge for me as well as others in the educational side, the research side to make this topic and this industry specifically the construction industry very interesting.

A: Okay, so you found it interesting but also challenging because it involves a lot of advanced technology like AI, AR big data, Clouds and things like that and those would develop or Implement industry 4.0 have to be specialized in IT. So, based on your concept of Industry 4.0. How do you think that's related to sustainability?

B: The impact in the construction industry could be major. It could have a disruptive way of making products really cheap and really good. Well the step on Horizon, right? That's the customer can choose more than they did because there's more flexibility in the end results and

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that means that you can reduce waste because you actually have a thicker way of producing these kinds of products that you really focus the different stations in doing on demand. There won't be any lot of changes when it's being applied on site because the customer has the opportunity to say in advance to configure their own solution.

A: So it's like the customer has an opportunity to co-create their product more.

B: Interesting idea of Industry 4.0 is that non-technological non-experienced people can design. They can create their own products.

A: From which technology do you think that should be applied?

B: That's a good question.

A: Like Augmented Reality? For example, like in car production. I have read that they use augmented reality to get the car visualized for customers.

B: Those technologies can be used. I think. There are two things that are intertwined. It's changing of a sector versus dream that this could be, right? It's a dream more than the future that could be. Those two things align a bit. Well, if it starts of course with the change of the building sector and it could develop into something over dream and also the excited future. The augmented reality we have is an example that it is really interesting that you can with your iPad's in front of your house. You can actually swipe your renovation on it and say this is nice and it looks in my street pretty good, this kind of thing. It existed already but there are a few barriers still but it is the way that customers can choose and then it can be fabricated in an instant or in a few days you can start production. The lead times between initial contact with the production and to delivering could be very short. Yeah, and what kind of Technology you can use? Yes, augmented reality, Mixed reality is also quite interesting and virtual reality. The technologies can really enable or enhance the way that the people can choose. In the end there are not a lot of cars being configured and bolts online. You still have a showroom that if you can talk to a sales person and say well, this is quite interesting. I need to drive this a bit. I need to feel for it. So, you have a sort of customer environment or the sales department that has a different kind of technology.

A: As you mentioned that the construction companies in the Netherlands are accounted for a lot of wasted in their production. Do you think that industry 4.0 would help them solve that issue in the production line?

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B: In a way it does! think so because in a production environment, you have more control over your waste process. It is a kind of lean methodology, where you can create reduction of waste in manufacturing, in the material waste and also in labor waste. I think industry 4.0 is actually creating a different kind of environment. This has to have a starting point, where you develop new ways of manufacturing within those environments. You have to change and you have to incorporate that culture or you have to chase that culture or develop new construction facilities.
A: Okay. So, you are saying that industry 4.0 can reduce waste in productions and also the waste that occurs from labor as well, right?
B: Yes! especially the labor. I think the production and the material waste in the current production environments is already very efficient. But if you have very dedicated machines that really have a few steps in handling, maybe it will get your flow of material and also the supply chain automated and connected to the production facility. However, the challenges for the company is how they develop into Industry 4.0.
A: This led to another question. So, what challenges do you potentially foresee if the construction industry implements industry 4.0?
B: The challenge would be the culture of the industry. People have to change their mindset on the production process that there is an alternative to upgrade production to cope with urgency such as climate change or disruption. Right now, people in the construction industry are not familiar with change, therefore, it is a challenge for them to implement Industry 4.0. Also, they lack knowledge of what beneficial the Industry 4.0 would bring to them.
A: What is the best way to implement Industry 4.0?
B: I think the construction industry is expert in project management. However, with this kind of change they need to adapt a lot. We have to create a knowledge-based community. We have to educate people in construction to create collective knowledge and bridge the gap. The collective action will also help to form the roadmap of the implementation of Industry 4.0 and also help us to lobby the government to launch policies that favorable to the development of the construction industry.

Interview 5	**Position: Lecturer**

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	Place: Online Interview
	Date: May 15th, 2020
	Time: 00:51:23 Minutes

A: So, can you tell me a little bit about yourself and your job?

B: I have an engineering background. I have a master at the Technical University of Eindhoven. I have a background in chemical engineering and a master degree in innovation management. I went for a job in Austria at a steel manufacturing company. I was working also in the automotive sector especially in production line, patent, research, cooperation between different companies and research Institute. After about 8 years, I was then working with the startup in the wind industry. We establish the company and that they have an exponential growth. We set up several production plants for manufacturing for wind turbines, and for engineering and after-service of these turbines. After that, I went to Hogeschool Utrecht to do research on startup and entrepreneurial activities. I have been doing this for three years now. I combined issues in the construction industry on topics like Industry 4.0 and the whole flow of operation that was required to make houses more sustainable. Besides, I lecture on a couple of topics such as sustainable development, technology management, quality assurance, system innovation.

A: Okay thank you so much for your introduction. Now we go into the second part of the question. How do you think sustainability is important for the construction industry?

B: Well, I'm familiar with the concept of the triple bottom line. I actually would like to add one more aspect to that. And that is circularity, because circularity is becoming a very fast-growing aspect within the construction industry as well. And that is a little bit neglected in the triple bottom line, in my opinion. So, from the cost perspective, my perception is that the margins are relatively low. If you look at the margins for most construction companies, they are very low. There is some dominance, especially in the Netherlands, of some large companies. So, competition is not always a level playing field. If you look at the environment. Quite often we are looking at environmental impacts by the efforts to reduce, for example, CO2 emissions, to isolate houses, to make it more energy efficient, to include more solar panels and things like

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that. On the other hand, I also see that we are introducing a lot of non-bio-based materials such as UBS or pure polyurethane or this kind of plastic materials. And from a circularity, sustainability point of view, that is increasingly environmentally friendly, of course. So, we are aiming in the good direction to make houses more energy efficient. And at the same time, we are moving away from circularity ambitions. So that is why I would like to also include circularity in the triple bottom line.

A: But then the circularity is about several "R", reduce, reuse, recycling and something like that that is related to environmentally friendly practices, right?

B: Yeah, that is correct. But yes, the environmental prevalence has as more aspects are making houses more energy efficient, but also how to use materials that can be reused after construction. The societal impact is an interesting one, of course, because in the Netherlands, it is quite known already that we don't have enough construction workers and therefore we have to attract them from other countries, especially Eastern Europe. And these are often low-level jobs. Yeah. And, yeah, it would be better for the Netherlands to attract more high-level workers and also change the way of working in such a way that get educated workers can have on that whole value chain.

A: Mm hmm. Yeah. So like right now, from your perspective, the construction industry is kind of moving forward to economic and environmental sustainability, right?

B: Yes. You can distinguish between renovation of existing houses and new built houses. Both strive toward more environmentally friendly buildings and also driven by the cost standards that are developed there. Of course. Because that's a driver.

A: So again, from your perspective you mentioned that right now the construction industry in the Netherlands is making an effort to reduce CO2 or create isolated houses or energy-transitions in the house. So from your point of view, do you think that many of the construction companies have achieved these goals or are they trying to make improvements or anything that you would suggest they do?

B: Well, the ambitions for the Dutch government are very high. Yes. So, we have a climate agreement that describes that we have to renovate thousands of thousands of houses. And I think that the industry cannot follow that speed of transition by their traditional way of working. So, innovation is required to disrupt these traditional markets and to speed up the

process of fulfilling these ambitions.

A: Ok. So right now, the companies are trying to find some alternative to serve the Climate Change Act, right?

B: Yeah, but as the industry is also characterized by large construction companies, they are not able to go into a transition to innovate. That's what I've been working in very large companies, it's quite logical, of course, that a startup company can be much more agile and adapt to changing environments as traditional large companies cannot. They stick to their supply chains. So they have their traditional construction materials with all their contracts and suppliers agreements. But also, their way of working is as traditional as it's a culture that is holding them back from innovation.

A: So, would you say that their traditional ways of working is a challenge for them to cope with the sustainability issue that's happening in the Netherlands?

B: Yeah, I tend to agree with that. At the same time, it is also an opportunity for them. And I think also if they can embrace that ambition. Gives an opportunity to grow and to increase their margins, that's a positive perspective. There's no opportunity if I look at it from a little bit more negative side. And then I would say their culture and their size of company is a big obstacle also to innovate.

A: Ok. So, do you see any other challenges that they might face in developing to achieve sustainability, apart from their culture?

B: Sustainability, again, is very broad. So, on what aspects of sustainability could they develop? I think there is quite some capital in this whole industry. So, from a cost perspective, I think that this is beneficial. As long as there is capital, you can also innovate. And I think that this whole industry, this whole sector has capital. On the environment's point of view. I think the circularity is becoming more and more emphasized also within the culture standards and also the demand from customers, the house owners. So, I hope that this is giving an incentive for large companies to move into that direction. I think the biggest problem might be the social aspects, that it's almost a little bit of a chicken and egg problem that at this moment we have a lot of workers from Eastern Europe doing their job and doing as they are told to be doing. And if you want to innovate, you also have to establish cooperation with all levels in the organization. The vertical integration that both construction workers, all the workflow needs to

get their input, how to innovate, but also the strategic engineers at higher levels. And as long as you keep working with foreign workers, you don't get continuity in your production process. And as you mentioned, as well as the societal aspect, could be that introducing Industry 4.0 aspects within the construction industry could give new jobs, better education jobs and also innovation within the industry. But if there are no workers and they are coming from abroad, then it's very difficult to to create this flywheel effect. It will be the job of the companies itself to find a way on how to educate them or to keep them working in a company or otherwise they will have to be laid off.

A: Yeah. How do you attract these kinds of workers?

B: Well, you can only attract them probably when you can offer a good job with innovation, with new ways of working. So that's why I say a little bit chicken and egg problem.

A: Ok. All right. OK. Now we are going to do the last question. So, it will be about your opinions on the implementation of Industry 4.0. Have you heard or I think you've heard it? So how do you hear about the concept of Industry 4.0?

B: Well, I've heard it from my university and onwards into my work life, of course, but I was more emphasized by the topic of Industry 4.0 When I was doing research in this construction industry. And what I actually noticed is that for the construction industry, this is a very new theme where many aspects of this concept of Industry 4.0 also from the PDF that you have sent to me tend to be quite well known already in the automotive. Sometimes I also have to think, okay, this is really a new concept or is it much more mature already for automotive and very new to the construction industry.

A: Okay, so is from your opinion it is a new theme for the construction industry but already implemented a long time ago in car production?

B: Yeah. Yes, indeed.

A: Okay. So based on your opinion, how do you think that Industry 4.0 is related to sustainability?

B: Oh, that's a good question. I think one of the most important aspects is that at this moment we see a lot of waste in construction sites because of poor measurements, poor supplies. Mistakes that are being made on the construction sites, excess of materials that cannot be reused because there is rain on it or there's dirt on it or whatever. And all these waste materials

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on the construction sites can potentially be eliminated when you have a better alignment of the whole value chain from raw materials to construction works and Industry 4.0could could improve that, at least theoretically.

Besides the waste production, I see a benefit in customization. So, in the normal value stream we have a lot of standard materials. So also, standard facades for houses and things like that. And when it comes to renovation, customers want to have a customized solution for their particular house. In order to facilitate that, you need to have quite agile production facilities that can efficiently produce all different kinds of assets and integrate solutions.

A: So, they may improve the product variety and the quality as well, right?

B: At least the quality of the site so that everything fits well together and fulfills the customer's needs. At this moment it is for customers to foresee what they can expect if they go into a renovation program and if they can have better information about the product that they are receiving, for example, by doing completely digitized measurements. AR has augmented reality how their new house and roof look like then that will also help them to make good decisions.

A: So, this leads to another question since you mentioned that the construction industry might use AR to foresee the customer's renovated house and to allow them to co-create so that they can improve sales. Do you think that there is any other Industry 4.0 that could be adopted in the construction industry to improve sustainability performance?

B: Yes, I think traceability is very important. With Industry 4.0, you can enhance the traceability of all your materials and all the data. Traceability of materials could then also help for the circularity because if you know exactly which materials from which side have gone to a particular building, then you create a sort of material passport. I don't know if you are familiar with that concept, but that a building has a complete, complete breakdown of all the components that went into that construction. So that after a use of the building, let's say, 50 years, the building can be reused, materials from the building can be reused in other buildings recycles.

A: Which technology enables traceability?

B: Industry 4.0 is about the data-driven and Big Data base of all these materials and then you can apply all the algorithms on that big data and say for example how much energy we have

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used in this building. You can make use of this Big Data in a lot of ways.

A: So, from your opinion, what challenge do you potentially foresee if implementing Industry 4.0 in the construction industry?

B: One of the biggest challenges is that you need to be small, to be agile and adaptive to different new technologies and you have to be large in terms of your capital to invest, especially with the ambition to establish a large factory and good IT system. That is a tradeoff, either the large company could try to be agile or the small company should try to acquire more capital to invest. I think that is a challenge to combine those. And also, for the worker, I think there will be a challenge to attract the higher level of worker. There are not enough engineers in the market.

A: So, three challenges are the culture, IT system and the HR that need to be prepared right?

Yes! So, what do you think as the best way to implement Industry 4.0 in the construction industry?

B: It is very important to think about the backbone of your whole organization. I think you need to have a strong IT backbone, which is robust and scalable and have a standardized platform to connect suppliers and suppliers. When production needs to be scaled up to a larger extent you run into the interface of the data point. You would use google cloud or something to store the data but then you have to realize about the security and control issue because you cannot control that system. So, the company should also be concerned with data security.

Interview 6	**Position: Software Developer**
	Place: Online Interview
	Date: May 19th, 2020
	Time: 00:58:04 Minutes

A: Can you tell me a little bit of yourself and your job?

B: I am job Koehoorn, I am working as a software developer at Dijkstra Draisma. One of my

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jobs is to automate the process from designing to the building. We make a house and put it up in 1 day. Everything is fabricated in our factory. I am making sure that all the robots and people are doing the right stuff. I try to automate that whole process beginning with the drawing from the architect, putting the robot to do the best stuff at the right time. That is a project that I am working on, most of the time.

A: Thank you for your introduction. Now we go on to the second part, which is about the company sustainability strategy. Can you tell me a little bit about how sustainability is important for your company?

B: Sustainability is one of the pillars of our company. We are working hard trying to make our product sustainable as much as possible. We have a few projects where we try some new materials for insulation. We stop using chemical components for the insulation because it has a footprint and is oil based. We try to make bio-based materials.

A: So, you are trying to use sustainable materials, right?

B: Yes!

A: Do you think of any other part of the company that is sustainable, besides the product?

B: I am not into that part of the company very much

A: According to your opinion, do you think that your company has achieve sustainability goal, any improvement

B: We are still working on a more sustainable product. We are trying to be more circular in a production process. We are trying to minimize waste to a minimum. We also try to get our waste to facilities where they can reuse it, so it is a way that we keep our circularity. My automating stuff would get help reduce waste and bring higher efficiency in production.

A: The automation that you mentioned, you mean robot and machine?

B: Yes! Robot and machine and also the software, which is a platform for the architect to draw on the design that is easy to change things around to get higher efficiency from your materials. We are also in the process of making data transfer from design to machine automate, which would help reduce paper work in the office. I think we are printing about 2000 papers/week only for the production. This will be reduced to zero with the software I am developing.

A: Do you have any challenges that you faced regarding sustainability issues?

B: One thing is the paper-based office that we are trying to eliminate. The time-consuming

process from design to production. It is difficult for us to identify if something goes wrong in the process. So, it requires a lot of re-generation of parts and that would not save up cost. So, it is more like a productivity point of view.

A: Ok! Now we go on to the last section. So, have you heard about the concept of Industry 4.0? How do you perceive it?

B: Yes, I have heard. It is something that we would like to have. We are in the stage where we are building the future factory. It would be great if that could be functioning like a car production. Everything will be automated and executed on the floor.

A: So, your job is involved in this future factory, right? You are making software to make the process integrated?

B: Yes! What we dream of we would like to have input from an architect from the drone that can completely scan and measure the building. We get dimension from the drone and that we can generate data and send it to my program. And then we can plan and produce from it. That part I have developed and we are in the process of testing out.

A: So, you can get an input from the architect and that the production can see the data that is ordered from the architect, right? So, everyone can see the same data across the value chain including the supplier?

B: In building a house, we have partners that produce parts of insulation, wall, floor and so on. We are trying to get them on board to automate this process. We are starting to automate the supply chain process so that we can get an accurate size of raw materials. This is happening in the design process so the architect can be accurate about the dimension of the building. But our supplier of insulation is messed up, we have a lot to re-generate because it is not flexible for changing. If we can automate the supplier, we can get an accurate dimension of part that we want and that would help reduce re-generation or redo work a lot.

A: Okay so do I understand it right that the software is working well within the organization but then the information is not connected yet with your supplier?

B: Yes! We are trying to get them on-board. They are not automated yet. I am trying to convince them to work in the same way as we did.

A: So, you are trying to get them a platform to create a digital supply chain network?

B: Yes! Next year I think it will be completed

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A: Do I understand it right that the data is collected from the drone and then it will be recognized in my program and processed for production?

B: Yes! We still need AI to automate a step to transfer data from architect to the program but then you have to build up the library of the data, which we are in process of building this. I will be building for some years to come.

A: Okay! According to your perspective, I think you have developed a kind of big data to automate the process.

B: Yes! I generate a lot of data, which is Big Data

A: Do you see any other technology that you would adopt in your job according to Industry 4.0 concept?

B: I mentioned that I would like to use AI. I see a lot of potential in using it in checking wall parts, defining what is what in a wall, how that should be detailed. I would like to use AI to check the elements. You could scan the wall and compare with the digital form if it is the same quality so that you wouldn't get any mistakes.

A: So basically, you would like to use AI for quality checking?

B: Yes, that would help reduce re-do work and waste it helps us to finish everything onsite. When we go on the site everything would fit well together. Last month we were able to build two houses in one day. There is no room for mistake since we have automated the design platform.

A: On the manufacturing, the data has been sent through CAT and BIM to the production and the labor is made for the product accordingly?

B: Yes! The labor has a task to put things together according to the design that finished in BIM. They all have a booklet that guides them to put every component together.

A: Now what challenge do you potentially foresee if implementing Industry 4.0?

B: Everyone has a different way of looking at automation. The challenge is how we can integrate knowledge to have the same understanding toward this revolution. Change management is a challenge. They have to find a way to automate their process, for example our supplier. We are facing challenges to make them automated.

A: So, the ultimate goal is to make a supplier integrated, right?

B: Yes! That would make our parts more accurate in term of dimension and quality

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A: Then, what do you see as the best way to implement Industry 4.0 in the Dutch construction industry?

B: I think we have to take it step by step. We need to keep up with the change that we are making and also recheck if the system is working well. Change management is important. We shouldn't force people to work in a way that they are not familiar with. If you change their way of working dramatically, there is a chance that they won't adapt to those changes. For my job, I teach people to work on the software like on the job training and organizing session to train them. I go to the station and give them an instruction for them to be able to do all kinds of stuff.

A: thank you so much for your time for the interview. You have provided a lot of input to me

B: thank you! I hope you succeed in writing a thesis.