Industry 4.0 in production companies in Europe and the United States of America: A cross case-examination.

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ABSTRACT,

This paper contains the research about Industry 4.0 in the context of purchasing, comparing the USA with Europe. Several American and European production companies were interviewed to examine the current state of Industry 4.0. Intending to gather information about their use of Industry 4.0, plans, and visions. The interviews from the companies that were using Industry 4.0 were used to write cases containing individual Industry 4.0 applications, visions and a special section about purchasing. Three firms used Industry 4.0. Further examining and comparing the applications and businesses led to more insight into the current state of Industry 4.0. Different companies have different reasons for implementing Industry 4.0: Optimize workforce, replace aging workers or decrease downtime. With company size having a positive effect on possibly implementing Industry 4.0, and the USA having more prominent companies in the food production sector, they appear to have an advantage. Companies are frequently unknowing, and thus incapable, in implementing full connectivity well. A difference in mentality is noticeable, as the European companies showed more long-term thinking, leading to them buying and developing Industry 4.0 solutions with the future in thought. A future where more machines are hooked to a system that connects everything. Thus encouraging themselves and others to pay more upfront for future connectivity. American companies mostly developed Industry 4.0 that served only their designed function; having management to approve everything, thinking short term. A further problem is availability and reliability of support personnel, them possibly being far away.
The construction industry in the USA is on the brink of a revolution driven by Industry 4.0 due to a decrease in workforce and increased digital infrastructure, yet needs high investments and needs other companies to follow along. Industry 4.0 in purchasing was not a priority for most businesses.

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Keywords
Industry 4.0, Cyber-Physical systems, machine-to-machine communication, Purchasing, future vision, Cross-case examination

9th *IBA Bachelor Thesis Conference*, July 5th, 2017, Enschede, The Netherlands.

1. INTRODUCTION, BACKGROUND, RATIONALE

The last three *industrial revolution*s have left a tremendous impact. Various before and after studies of markets and society show the impact of the industrial revolutions. (Feinstein, 1998; Atkeson & Kehoe, 2001, 2007; Steward, 2015; de Vries, 2000; Jensen, 1993). These studies give a strong indication that technological advancement impacts the development of markets. It is inevitable that industries will continue to develop, so it is essential to be able to understand and predict what will happen next. To adapt appropriately to the industries and maintain a healthy market, we must look to the future at Industry 4.0. In this next stage, we will use machine-to-machine communication and Cyber-Physical systems to execute a process without human intervention. Companies are turning to automation to compete, innovating their way to advantages. Not only is this modifying the financial burden of employers paying employees, but it is affecting the working atmosphere. From an academic perspective, we can evaluate companies which are active in the technology movement; we can measure the impact of their innovations. This information can be used to develop a plan for the market, called a roadmap (Schiele, 2017). Through using the technology roadmap, we can determine the needs of a company, and the most efficient way to reach those needs using technology. Furthermore, the more we know about what innovations are available and how implementation can happen, the better companies can adapt to it.

In this research, we gather information about Industry 4.0 applications in two different markets: The United States of America and Europe. To gather this information, (manufacturing) companies will be interviewed (see *Appendix A* for interview questions). Created are, following the interview, case studies for applications of Industry 4.0. A cross-case analysis made from these cases will be made comparing Europe to the United States of America. The visions of the companies will be included in the study.

According to Schiele (2017), there is a potential for Industry 4.0 in purchasing. In search of applications of Industry 4.0, we will consider applications regarding purchasing. Questions shall be put upon those companies regarding purchasing whenever possible. The knowledge of non-purchasing related Industry 4.0-applications is valuable on its own.

The intended contribution of this thesis to the field of Industry 4.0 and purchasing is to give (practical) insight into the ways of how American and European companies are adapting Industry 4.0 application. A variety of industries is going to be researched. The vision of those companies and their industries will be taken into account. Those visions may or may not differ per region.

The German government is actively promoting (research in) Industry 4.0 (Deutscher Bundestag, 2017 p. 35). The little information that is known mostly originates from Germany. Not much information is available about Industry 4.0 in the United States of America. The more in-depth goal of this research is a cross-case analysis.

2. THEORETIC FRAMEWORK

2.1 Purchasing

Purchasing defined as, *"obtaining from external sources of all goods, service, capabilities and knowledge which are necessary for running, maintaining and managing the company's primary and support activities and the most favorable conditions*" (van Weele, 2002 p.14), is done when there is a need for supply. The purchasing process is currently carried out through a purchasing team through manually selecting appropriate suppliers and analyzing their offers based upon various parameters such as cost, availability, and warranties. These parameters determine which supplier best fits the company's needs. The purchasing team evaluates each supplier through these parameters: (5 Rights of purchasing): "Getting the right products and services to customers at the right *time*, *cost*, *place*, *condition*, and *quantity*" (Mason-Jones et. al., 2000). Those parameters are taken into account, chosen as a supplier is the highest-scoring supplier. This supplier will deliver the goods to the company until they are asked again. Companies are prone to use familiar suppliers for a new contract due to personal ties (Wuyts & Geyskens, 2005), a cost analysis, or a contractual process.

This entire process is costly and therefore in need of innovations. At the beginning of this process, purchasers can only select several parameters which limits their starting list of (potential) suppliers. This limitation of parameters is a disadvantage because it limits the number of offers from which the company can choose. However, other companies are turning to automated computerized purchasing systems which perform automatic transactions and cost analysis (US5878141). There are more automated systems that are upcoming, as laid out by Schiele.

The *first system* has a sensor that analyses when a shortage of materials is upcoming and directly purchases the materials from a pre-selected supplier (to be delivered at the right moment).

The *second* system is similar, but it extends the process by Cyber-negotiating with different suppliers. Automatically analyzing their offers based on many more parameters than the purchasing department could ever do manually. The system then orders entirely automatically.

Those systems have been proposed or partially developed. Respectively, these systems take on the name of *'tightly-linked systems*' and *'loosely-linked systems'* (Schiele, 2017, p. 3). Developments in this area mostly serve the purpose of automating firms extensively and creating a more efficient and faster overall process. Schiele discusses the relevance of Industry 4.0 in purchasing. Now that the purchasing department can analyze seemingly endless parameters from a vast number of suppliers, a Cyber-negotiation can be conducted which leads to the best-picked supplier. (Schiele, 2017)

2.2 Industry 4.0

Industry 4.0 is a term that came up to define technological advances that serve towards the goal of Cyber-Physical systems and a fully automatic factory. These technological advances can be seen as a component in the *fourth industrial revolution.*

The *first* industrial revolution (Evolving period between 1760 and 1820) was set off by the invention of the steam engine. It brought mechanization, water-power, and steam-power to the factories, which increased production tremendously. (Atkeson & Kehoe, 2001; Dombrowski & Wagner, 2014)

The *second* industrial revolution (1870-1914) was set off by the invention of the electric generator. This revolution had electric power (engines) as its key component, further mechanizing the industry with stable power and mechanical possibilities. Mass production of the Ford T-model is seen as a vital example of this revolution. (Atkeson & Kehoe, 2001; Dombrowski & Wagner, 2014)

The *third* industrial revolution (1971 - ongoing) was set off by the invention of the microchip. It had the advancement of analog technologies into digital electronics as its key component. The mass production and use of digital logic circuits, internet connectivity (ICT) and the automation of production processes (robot arms, e.g.) were vital forces in this revolution. (Atkeson & Kehoe, 2001; Dombrowski & Wagner, 2014)

The *fourth* industrial revolution has the embedding of technology in society and the human body, Cyber-Physical systems, artificial intelligence, bio/nanotechnology and autonomy (cars and machines) as its principal components. And is currently ongoing. Its exact starting point has yet to be defined. (Dombrowski & Wagner, 2014)

Industry *4.0* is the autonomy of machines and the embedding of technology in society. It can be seen as a movement, an evolving wave. The goal of this technological movement is to create companies where everything runs automatically without the input of human effort.

The *first* component of this movement is the linking of machines to computers with machines to exchange data between machines without human interaction; this is called **machine-to-machine communication** (Schiele, 2017, p. 4). One example of machine-to-machine communication is a microwave that sends the owner a message on his smartphone when the time is there to remove the food. A human can still be involved in this process to retrieve the food, but that microwave is a machine that communicates with the smartphone (another machine) while retrieving the data from the time-sensor. An inter-connectivity is in place. If this communication happens in a Cyber-Physical system in industry, we can call it an Industry 4.0 application.

The *second* component thus is the **Cyber-Physical system**. This is a mechanism controlled by algorithms which are computer-based and "*offer close interaction between the Cyber and the Physical components*" (Khaitan et al., 2015, p. 1). A widely accepted definition (Parolini, Toliaz. Sinopoliy, Kroghy, 2010; Shankar & Islam, 2009; Jacob, Zhang, Zimmerling, Beutel, Chakraborty, Thiele, 2017) comes from the National Science Foundation, who defines it as a system "where physical and software components are deeply intertwined, each operating on different spatial and temporal scales, exhibiting multiple and distinct behavioral modalities, and interacting with each other in a myriad of ways that change with context." *(NSF, 2010, p. 1).*

In other words, the Cyber-Physical system is a deeply integrated system where both the software and the physical component interact, changing production processes. They each have their part to control, yet they work together dynamically depending on the context. E.g., an autonomous car system where sensors (cameras, Infrared) gather information from a continually changing surroundings (the outside), to change the direction and speed of the wheels, therefore drive. The Cyber part is the software that gives out commands to the physical part, the machine that changes the course and direction of the wheels.

If we can add a machine-to-machine communication to this system - e.g., a system in a company that recognized that the company needs supply, who will tell the autonomous car to pick up supply and delivers it to the firm - we have Industry 4.0.

Industry 4.0 should be seen as a dynamic wave of technological innovation, with the common goal to make machines more connected and lower human control in industries.

3. METHOD

Interviews are held at several firms. If looked at the time planning of a few weeks, performing three interviews in the United States of America and at least three in Europe is an attempt to extract information. Those interviews can either be held in person, or via phone or email; as some firms would prefer direct contact and others indirect contact. The goal is to extract Industry 4.0 applications from those firms and form those into case-studies. With which we will conduct our cross-case analysis from.

The use of case studies is not undisputed: Johnson (1994) mentioned the lack of scientific rigor, reliability and generalization ability as criticisms against case studies. However, it can provide a holistic view of certain phenomena or series of events (Feagin, Orum, Sjoberg, 1991) since many sources (in this case interviews) are or can be used. For this research, the most important advantage of the case study is for it to be useful in capturing the emergent and fundamental properties of life in organizations and the flow of the organizational activity. This is especially good when it is changing very fast. (Hartley, J., 1994). The use of case studies for this research fits the theory as the research is trying to capture a glimpse of how and what companies are doing with Industry 4.0. It is also expected that the environment is changing very vast.

One may not assume that all firms know the full meaning of Industry 4.0 and its usage. Brief introductory questions will be asked in order to find out how much the companies know about Industry 4.0. We also proceed to ask about their visions for the company/Industry 4.0. Then a few questions regarding the existence of, and implementation of Industry 4.0. In the case of (planned) Industry 4.0 applications, questions will be asked regarding the implementation of Industry 4.0 in the context of purchasing. In the end, questions will be asked about previous projects or partial implementation of Industry 4.0 and potential projects.

It is expected that the interviewee will provide information that will lead to a better in-depth view of the company. Any useful information will be written down and made use off by placing it to the question-chapter most suitable or at the end of the interview. The previously described order of questions is not mandatory. If the interviewee can (partially) answer several questions at once, the interview will be guided that the information will be gathered that way.

In case of insufficient knowledge by the interviewee for (technical) questions, an appropriate person will be asked to join the conversation, such as an engineer or the CEO.

One can expect that several firms do not do anything with Industry 4.0 or simply do not want to say much. Any visions or valuable information are processed in the paper. All interview material will is placed in the appendix. The written cases will be sent to the companies for fact-checking.

4. DATA ANALYSIS

Dealing with several cases a cross-case analysis is done to process the gathered data further. The unit of analysis is thus a case. To further analyze the data, the data needs to be ordained. A distinction will be made between the Industry 4.0 cases of the different companies, the future visions with background information and all data related to purchasing. For this, the Industry 4.0 applications has to be identified in the interviews. The cases that the companies mentioned themselves when directly asked about Industry 4.0 usage in their operations will be used firstly after being checked for the requirements of Industry 4.0. Then in the rest of the data, usage of machine-to-machine communication is identified in the companies' operations. With that in mind, Cyber-Physical systems can be identified, where if the two are pointing towards the same system, it is a valid Industry 4.0 application. It is then listed as an individual case for the company. When available, the problem and the Industry 4.0 solution are mentioned together.

In relation to the purchasing part, the *current* state, the *wanted* state, and the (*potential*) *problems* are listed and later discussed if available. This is done by identifying the parts where the company talked about purchasing and their purchasing operations and listing it in the chapter.

After the usable data has been isolated in the chapters, the analytical part will be executed. Here (chapter 6) the future visions, problems, and issues related to the United States of America and Europe will be discussed. When possible and when needed, external sources will be used to see how far-reaching each problem or opportunity is that will be discussed. Statements from the experts from the companies will be considered. As two of the most critical companies include the (de facto) CEO, they can be seen as reliable. In Company B, the interviewee was responsible for the company tour. By working as a chemical engineer his technical knowledge and a general overview is expected to be highly accurate. But for extended technical understanding the principal engineer has been asked alongside him. Current knowledge is highly accurate, but possible foresight and external relations can be seen as too unreliable for this paper, for that might not be his field.

5. CASES

5.1 Industry 4.0 applications

5.1.1 Company A

Company A is developing, using and selling food processing technologies; these are some of the Industry 4.0 applications used by them.

Example 1: Error management system

Error management systems are developed and implemented for companies. The machines that *can be* linked (via several ports and protocols) *will be* linked with Profibus. Which then travel to the programmable logic controller. By using Profibus, it is easy to filter out malfunction signals. The system will act upon them in a myriad of ways; lower speed/temperature, reboot, alternatively, merely display what is wrong. This way the numerous shifts are notified about frequent malfunctions and can prevent problems from happening again if the programmable logic controller cannot restore order permanently.

Example 2: Refill-corrected silo dispenser

See Appendix E and F.

In food production, batches of meat drop into a sorting line within a silo. Dropped each time are meat batches of 5 kilograms. As the product density changes, the weight of the silo is calculated until 5 kilograms is subtracted from the total weight. Once empty, the silo is refilled. If this all happened in one process, the weighing and subtracting would cause inaccurate batches. Therefore, the system stops the line that is dropping the batches as soon as it detects a refill is happening. Once completed, the silo weight is recalibrated and the line restarted.

Example 3: 3D-enhanced portion cutter
See Appendix B.

Products need to be cut in a certain weight (X) depending on the buyer. A product (fish) is fed through the infeed belt. At this point, a 3D-laser scanner calculates the distributed weight of the fish, whereas a computer calculates where to cut. As output, a color 3D-scan is shown on a display which shows the fish with head and tail and the cuts on the main body that would make X gram In the case of fish, the head and tail are cut off. The fish moves to the cutting machine. The cutting machine receives information on where to cut from the previous one via software. As the knives are adjusted, pieces of X gram (+- 2 grams) come out of the machine and are processed further on the outfeed belt. The product's location is adjusted automatically by the 'automatic product holder'. If needed the machine can switch very easily between a multitude of final weights and cutting angles, all depending on the demand. The optimum gap between the infeed and the outfeed belt is adjusted automatically.

Example 4: (constructing an) automatic factory management system
Programmable logic controllers control the factory. Using a Management Information System as a database to store (current) information of all 42.000 (meat)crates in the factory. From the moment the product is placed on a meat crate, until the moment it leaves the factory an almost complete overview of them is held by the system. Barcodes identify them with corresponding information which are scanned as often as possible. The unconnected machines mostly already have LAN-ports, for future connection use. The system will control the speed and settings of the different machines and belts connected to it, based on how many crates it calculates to go where. Harvesting happens at the end. Where the product is 'harvested' from the crate, upon which they are cleaned. The total weight of input and output are data entries in the system with which it can and do calculate the yield and efficiency. At all times the wholesale customer can see in which state their product is and when it will be ready.

5.1.2 Company B

Company B is an American company producing crackers; these are some of the Industry 4.0 applications used by them.

Example 1: Cracker weighting system with speed adjustable supply-system
See *Appendix C.*

A supply of crackers - baked and ready to be packaged - is rolling on the central conveyer belt (A). At the beginning, they are weighed to reach 6 gr before packaging. The main conveyor line (A) drops crackers to another line (B) by rolling. If it goes slower or stops, respectively less and no crackers drop. Above that, a laser is installed, that measures the level of the crackers that is about to drop into (C). The object (C) is a bigger weight measuring system that supplies crackers (by gravity) to the metal weight boxes (D) below, which open to drop when filled with >6 grams of crackers. After (D) they get put into plastic, and the system ends.

The supply of crackers varies and is not constant in all parts. Giving the metal boxes too little crackers causes a delay, but giving it too many too might cause a failure/error. Industry 4.0 is applied here via a central software system controlling all the machines mentioned. Data comes from two parts. The metal boxes that tell the system how fast they fill up, and the laser telling the computer the height of the crackers about to drop into (C). If the computer sees that the metal weight-boxes are filling up slower than usual, it can increase the height of (B) by increasing the speed of (A). The higher the level of (B), the more crackers are going to drop into (C) per second. The laser keeps notifying the computer at what level it is, and the metal boxes still have that sensor that notifies the computer about the speed of each drop. Once the system recognizes that the supply is too high and the boxes cannot keep up anymore and become inaccurate, the speed of (A) and (therefore) the level of (B) is adjusted.

Example 2: Proactive speed adjustment in the dough processing line

In the dough processing line there are several machines over a length of 20 meters that process the dough. Here the dough is almost done and only needs mixing, stamping and pressing and so forth. Computers are linked to sensors on the machines.

The slowest machine is always the bottleneck. Speed can vary greatly, and if one machine (e.g., the presser) is too slow, another has the risk of processing too much and wasting it or causing an overload which can be a risk to more significant error.

The computer interacts with all the machines (the presser, mixer, and so forth) via the sensors. Those sensors give the computer data about the processing speed per machine. If one machine causes a holdup, then the computer will communicate to the machines that came before that one in the line to adjust their speed. Say we have machine 1,2,3,4,5,6, and at the end, 7. and machine four can't process the dough quickly enough, then the software will tell machine 3, then 2 and then 1 to work at a slower pace, having calculated that speed from experience.

5.1.3 Company C

Company C is an American contracting company. The company constructs buildings. 'Example 1' is the Industry 4.0 application currently used by them.

Example 1: GPS enabled Modelling software

The key for Industry 4.0 is accurate data and software that can manage it. This company is using Cyber-physical systems on the construction site where theodolites (which is a surveying tool used to measure horizontal and vertical angles) are linked to Building Information Modelling software that creates accurate 3D models of the proposed building. Building Information Modelling can interact with the real world through GPS, to get accurate location data (points). This data is available to be used for the virtual mock-ups for customers. Also for construction work management and to find and prevent mistakes in the building. The system can give enough data to help with critical changes in the supply chain, quality control, and vendor coordination but cannot act on its own yet.

5.1.4 Overview in table

In *Table 1* an overview is given of the full state of the Industry 4.0 applications. About whether they are full Industry 4.0 or only partially developed is argued Industry 4.0 is an evolutionary process, and the process needed is written down in the table as well.

Table 1

Analyzing the Cyber-Physical systems and machine-to-machine communication prevalent in the examples.

Application	Cyber-Physical system (CPS)	Machine-to-machine communication (M2M)
Company A *Example 1*	The error management system relies heavily on CPS, where a system can interact with the machines to prevent errors from happening. The current state of the CPS in *example 1* is still relatively basic. The more machines [Physical part] are linked to the system that oversees the factory [Cyber part], the more complex CPS integration can happen. The company is investing in further integration.	In the current state the error management system is only controlling very few machines. Those machines send data to the system in order for that system to analyze it and act upon them via communication with the machines. All machines in the network communicate with each other via the system. More connectivity is in the making.
Company A *Example 2*	A CPS is prevalent in this application. The system [Cyber part] controls the hatch [Physical part] in the silo that allows produce to drop in batches. It also manages the data from the scale, using that to decide when to open and close the hatch or to refill the silo and therefore the further production line [Physical part]	The scale is communicating with the CPS about the weight of the silo. With the data from this *sensor* the CPS can run. The machines in this system (hatch, supply and outgoing line) are not communication but only get commands from the system. In order for this application to become fully Industry 4.0, it needs to connect to more machines that exchange data. The company chose for the current option to not overcomplicate the system, as M2M is not necessary for this system to work in its current state. Once other parts of the production lines are automated, the intensification of M2M (and linking up with other systems) on this application is relevant.
Company A *Example 3*	The CPS is fully controlling the machines linked to cutting the produce in the right way [Physical part]. Sensors analyze the fish and adjustments on the knives are fully done by the computer [Cyber part]. The computer is also controlling the speed of the infeed and outfeed belt based on data gathered.	The 3D-scanner sends the data it gathers from the scan to the cutting machine and the automatic product holder via the computer. It can be argued that the 3D-scanner is not technically a machine but solely three cameras, therefore a sensor. The speed of the infeed and outfeed belt is adjusted automatically. This indicates that at least indirect communication is happening between the machine that adjusts the belt, the knifes and therefore the automatic product holder. Further linkage to the error management system is part of the evolutionary process, adding more M2M to the system.
Company A *Example 4*	The automatic factory management system is under construction. Its designed purpose is to be the overseeing (Cyber-Physical) system, connecting and running each and every single machine, sensor and line. All machines [Physical part] with sensors that the crates travel through are communicating with the system - which controls it. Further integration with the machines currently without sensors is planned and part of the evolutionary process in	Machine-to-machine communication is what the company had in mind in producing the machines. All newer machines have a LAN-port to connect to the system when it is ripened enough. Currently only a portion of the machines communicate with each other via the system. The most noticeable communication is between the device from the wholesale customer and the machines from the entire factory. At any given moment the customer can see in which state their product (that is

	creating a fully automatic factory management system that manages all parts of the process. Another Cyber-Physical system in the making is the fact that the customer can tell his computer to interact with the automatic factory management system and therefore the machines connected to it. The computer can request the information about the current state of their product, which is communicated through the system. The customer's computer would need more direct machine-control in order for it to become a real CPS. The future of this is unsure.	currently processed) is in. This will only further evolve with more data flow when more machines are connected. The communication is currently already extensive, as the location and state of every crate is known to the system.
Company B *Example 1*	In this application, a central computer [Cyber part] controlling the switches [Physical part] with data it gathers from the scales and lasers. It is a fully functioning CPS. Control could be extended to the latter part of the line, where the packets are counted, using the data from the scales.	The cracker-supply switch with the laser are communicating with the packaging machine with the scale via the computer. This communication means M2M, as the data from one machine influences the other. The system can be extended through linking the machines to a central hub, managing all the data from the factory.
Company B *Example 2*	A computer [Cyber part] is managing the communication between the dough processing machines [Physical part] and will calculate and send out signals to the other machines about speed adjustments. The interaction between the Cyber and the Physical parts is close in this application, as Khaitan (2015) mentions a CPS should be. The current state can therefore already be seen as 'evolved into Industry 4.0'.	All machines have sensors and passively signal each other to adjust speed and therefore the flow of the line. The communication is kept simple but efficient. Proactive speed adjustments when delay is detected is what the system needs to do and is currently doing. As an evolvement of Industry 4.0, the machines could interact with the supply line, clearing a path to full stock control.
Company C *Example 1*	The building information modeling software [Cyber part] is 'controlling' theodolites and GPS-satellites to gather surveying data. Which is then used for virtual mock-ups. Currently the Physical part of CPS is not fully implemented. As the Theodolites and GPS are only sensors and the satellite are not machines that are being controlled. The data helps create virtual mock-ups which once again are not worthy of the Physical part of CPS. The next step for the data would be to implement it in the supply chain while adding a physical part, slowly adding more machines to the system.	A satellite is sending the data requested to the software, as do the theodolites. Those are the only physical parts in the system, yet not worthy of being called a machine. They don't communicate with each other or any other 'machine' yet, but that is to be implemented. The application is in an early stage, and slowly more machines are added to it while simultaneously adding more data flows to the system. In short, M2M has not yet evolved but is expected to.

Note: Application = Application in use; the Cyber and Physical parts of the CPS have been highlighted with [Cyber part] and [Physical part] For extra clarification of their existence; The examples refer to the examples mentioned in Chapter 5.1

5.2 Future visions, drivers, and enablers

5.2.1 Company A

Company A is systematically adding LAN-ports to newly sold machines. This implemented foresight gives companies an advantage for the future because it prevents costly replacements or adjustments of machines that lack communication ports. Communication ports and thus possible data flow are required for implementing Industry 4.0 and data management systems and make it easy to connect if they are already there. Adding ports increases the cost by a fraction. This shows a strong desire to continue in Industry 4.0, visioning it taking over most parts of the factories. While not knowing what specific technologies the factory of the future will hold, they know that everything runs through software. Data, acquired through ports, is therefore essential. New machines and technical solutions are created when the opportunity arises, and do not always require a direct profit. Great potential is being seen in malfunctioning management systems to prevent errors from happening in the first place. Malfunctioning systems are designed to save time and money of its users and give them a competitive advantage.

Companies might be reluctant to invest in Industry 4.0 due to the cost. Company A is therefore providing financing solutions to their clients. The companies pay off (cost saving) Industry 4.0 applications with the money saved by that application. A company that acquired a sorting line through financing re-earned it within the timeframe of a month. Help is also offered to give the old machines a new purpose.

5.2.1.1 Purchasing and sales

Sales happen on a large scale with natural products with varying prices. The customers of the processed goods do not prefer to order automatically, as they wish to be informed of the daily price, and might consider buying elsewhere or later. Ordering is usually done by phone and then placed into the system for further processing in the company. The company itself buys (relatively) unprocessed fish and chicken, which is also a natural product with irregular growth. Industry 4.0 (purchasing systems) require reliable (growth) data to work with to function. In the EU, animals are seen as "sentient beings" (EC, 1998), and cannot be pushed and manipulated too much. If x kilogram of meat needs to be acquired, it is difficult to identify the life stage and weight of each individual animal. A solution has was developed for letting the animals walk over scales individually. Upon which calculations are performed on that data for Industry 4.0 (planning) use. Company A is not familiar with many companies that have implemented this system.

According to Company A, due to the scale and rules in the United States of America, automating purchasing in the food industry is easier acquired. For if x kilogram of e.g. chicken need to be transferred and processed by tomorrow, the chickens are just rounded up till the approximate number is reached and are then processed. The increased ease with suppliers helps with automation. See also *Appendix D*

In the near future, Company A is not interested in implementing Industry 4.0 related purchasing applications. However, they see high potential in other food processing companies. With a specific target on ready meals for senior citizens, this due to the ease and difference in size of orders. As they are much smaller, they could be ordered individually from the internet. Machines would add and handle the ingredients for the meal box and it would be delivered to the pensioner's home.

5.2.2 Company B

The company sees Industry 4.0 as a great opportunity. It is seen as a way to do more work with fewer people. All while decreasing the failure rate and downtime. The company has *two* upcoming Industry 4.0 applications, which confirms their interest.

The first is a system where the ten packaging machines work together to manage the demand. If one slows down or is in repair, the others will increase their load. See *Appendix G.*

The second is the total automation of the 'Square cracker line'. In this line, the flow of crackers is straightened by employees before they are packed in plastic. This is done with their hands and requires beyond five employees. The system would replace the workers hands with the use of robot mechanics whom are guided by lasers. It automatically detects any error or interference. Being able to *then* shut down the line directly, the system prevents mispackaging and company waste. The system would even count the flow through rate and weight of the packages, adding them up to three kilos in a box. This system removes the need for employees working as package counters and could provide data for further automation for the supply lines.

Problems however, arise with financing. Management must approve every project and see a direct benefit in it, especially if there is a direct adverse effect like retraining workers. There is seldom any long-term thought. Direct profit maximization has priority over cost-savings achieved by long-term thinking and investing. If something gets approved, later connectivity issues can arise due to only allowing the cheapest option, thus excluding ports. The machines would need massive (expensive) adjustments or be replaced completely if the firm wishes to achieve full industrial control.

Holding back the development of Industry 4.0 in this company is that the work of the software could be done by an employee for a few minutes every so often. By using an employee, they would not need to increase spending on adjusting the old machines which might need adjustments again. External engineers familiar with specific Industry 4.0 systems can also be hard to find in a rural state like Vermont. When issues arise, the machines could be down for several days as an engineer might need to come from another state or country.

However, the thought the company has is, that if more businesses (in the area) implement those technologies, more people familiar with the technology will become accessible and the process of implementing those technologies will have a lower threshold.

5.2.2.1 Purchasing and sales

Purchasing is currently done by hand on an excel sheet. The output and loss data from the form is entered into excel. Automatically this is subtracted from the inventory. An order is created and must be executed by an employee when the stock hits a particular low.

The company is planning a new purchasing software, with the hopes of increased automation. However, the company does not see the new purchasing system as their priority. The action requires five minutes from an employee while more significant issues have a higher importance. The suppliers are plenty and constant, thus leaving a way to a tightly linked purchasing system (Schiele, 2017).

5.2.3 Company C

Company C sees Industry 4.0 as a possible solution to their problems. The labor-intensive construction industry lacks skilled craftsman and supervisors. An aging workforce intensifies the problem. The sector needs technological advances to achieve more with fewer workers, become safer, and therefore, decrease costs. Those technological advances can now be accessed due to the required infrastructure becoming a reality. In the case of Company C , this concerns fully implemented cloud (computing) and available wireless communication on, in this case, undeveloped land. With the infrastructure in place, the company sees a future in applying technologies such as (GPS connected) theodolites, 3D-printing and a multitude of sensors, which can be connected directly to the system on-site.

For the implementation of Industry 4.0 liquidity is of importance. Company C is a big company with the budget to invest in such a system and help ripen the process in the hopes that it will be evolved enough for others to step into the market. They believe that if more companies start using the technologies, the industry will go through a revolution. To get there, investments to train employees on the use of these new technologies are needed, as well as general acceptance of the technology. The company mentions challenges with building modular buildings as a sign of the non-completeness of the system. Which it hopes to get a breakthrough in the future. Next to that, they wish full interconnectivity in their technology and wish to use 3D-printing in situations that could form a danger to the worker. The firm sees the 3D-printing of high-end materials as a way to get quality material on the field while replacing several (dangerous) processes. Industry 4.0 is seen as a way to increase safety and be more efficient.

5.2.3.1 Purchasing and sales

The company is not sufficiently clear about any changes made to the traditional purchasing process. However, quoting from the interview from *Appendix K* can reveal their strategy: "*We are using Virtual Modelling of apartment unit mockups to walk our customers [...] through their apartment before we begin construction.".* From this quote, we can grasp that the company wants to enhance the purchasing experience by letting customers not only view, but also walk through their future product.

Buildings are not items that are bought on the go and take time, consideration and planning. If looked at the purchasing department of the company (subcontractors), they are maintained and acquired through personal contact and chosen per project. The company invests in subcontractors by having an exclusive subcontractor's day amongst other things. All this shows the willingness for a personal relationship with them. Automating the choice of those subcontractors with Industry 4.0 appears an unlikely scenario.

6. CROSS-CASE EXAMINATION

In this chapter, the cases will be discussed, compared and further examined.

According to Company A, there is a clear difference between food production companies in the United States of America and The Netherlands. They state that the food companies in the United States of America are usually made up of larger companies. It is therefore hardly possible for a single boss to oversee each production line simultaneously and provide solutions issues. As a company grows and expands, it needs to be controlled by a larger workforce and more efficient technological innovations. A significant innovation that Industry 4.0 provides is monitoring systems which give an overview of the factory while managing any malfunctions. The thought is that the bigger the company in the industry, the more likely it is to have Industry 4.0, as a single supervisor cannot have a complete overview anymore. Company A mentions that bigger companies easier go over budget (for implementing new technology). Kerzner (2017) agrees and argues that it is *"Because the **smaller company** incurs greater risk with the failure (or **cost overrun**) of as little as one project, costs are generally controlled much more tightly and more frequently than in larger companies" (Kerzner, 2017, p. 338).* A bigger company has more room for failure. The company mentions the heavy use of Industry 4.0 in one of their customers, Huskins, in Enschede which is a big food processing company.

In The Netherlands, the companies are usually much smaller. This is stated by Company A, but be backed up by statistical data. The OECD database from 2017 about company size is used here. In the database the *amount* of large companies in The *Netherlands* and *Europe* in general is much smaller than in the United States of America. This is true for all parts of Europe except for Germany, which has a substantial but still lower share of big companies than the United States of America. The small size of companies throughout Europe allows for one supervisor to (micro)manage all the production lines. During a malfunction, workers can be informed quickly and given instructions on what to do. As company size is smaller than others, one manager can still lead the company efficiently to streamline all processes. Therefore, "expensive" investments in Industry 4.0 have *less priority*. The fact that in Germany a larger amount of companies are considered as 'large' could be an explanation why (the term and research of) Industry 4.0 was born in Germany. (Klitou, et al., 2017)

As mentioned before, a more prominent company is more prone to go over budget. In Company B, we see that the (partial) Industry 4.0 applications are implemented without further thought of linking them to a bigger system. They are also relatively simple and serve only one purpose. For example, the "proactive speed adjuster" that controls the flow of the dough through several machines and helps prevent holdups and waste. This system is solely designed for that purpose. Whereas the computer running the Industry 4.0 application could have been designed differently, as for getting the upfront investment of a LAN-port for easy data flow for a more connected factory. The same goes the *'cracker weighting system with speed adjustable supply-system'*- application. Here the weight data could be used for many other processes while being very difficult to obtain without connectivity possibilities. The same goes for the metal detector that is saving the company money but could have had a few adjustments and be linked to the system where it could work together with the rest. The interviewee mentions that it takes a long time and much effort to ask for approval of such systems. Short term profit maximization is always in the heads of management, even though long-term thinking is frequently better for the company in the long term, yet might be more expensive upfront.

Company A recognized that short-term thinking is the wrong way to implement Industry 4.0. Looking forward to having a factory where everything is connected, and things flow automatically. Company A implemented a plan that the machines should be easily adjustable and implemented to the overall system. Not selling the metal detector without LAN-port (connectivity) is one of the ways to show that. Being more expensive upfront, cost-savings will be achieved in the future due to lack of adjustment costs.
Company A goes one step further and offer to finance cost-saving Industry 4.0 technologies, where the saved money is paid off to them till the clearing of the bill. Going the extra mile in standing behind the idea that sufficiently implemented Industry 4.0, if done strategically, will save a company enough money in the future to be worth the investment.

In their interview, Company B mentioned that their more prominent supplier (Dot foods) had everything connected with scanners and computers. The connectivity is pointing towards full use of Industry 4.0. However, they found the data that the company was sending them about an error with a batch not useful and a waste of time. As the data that they needed, couldn't be supplied quickly.
The company had invested much money in what they doubtlessly thought was an excellent Industry 4.0 system with more connectivity and more data output being a better system. However, constant messages about the future orders only confused Company B. The system was incomplete in that if they found a bad batch, it did not have the possibility to find the information needed to identify and remove that batch of product. In this case the best-buy date.
The case of Company C tells us that a revolution in an industry does not come without effort. Teething troubles arose in the modular building construction. And in order for Industry 4.0 to fully breakthrough, the company is stating that others need to follow suit and help innovate. Henceforth innovation, maintenance, and knowledge become easier to obtain for everyone. Company B gives as a reason for the slow evolvement of Industry 4.0 innovations in their region the lack of nearby technicians. If Company B is one of the very few companies to innovate and use new technologies, it will be more challenging to find suitable (repair) technicians. Company C mentions retraining many of their staff as something that is to be done, it is implied that this is to not rely on external technicians. Company C has the resources to innovate and retrain their own staff as it is big enough, but it might be difficult for a small company like Company B to innovate and maintain in Industry 4.0.

All *three* interviewed companies that gave Industry 4.0 applications have a different driver and approach to it.
For Company C a key driver for Industry 4.0 is the lack of skilled craftsman in a labor-intensive industry. Where Industry 4.0 would fill in for the workers that cannot be found.

Moreover, in Company B, the opposite is happening. Industry 4.0 would replace some tasks workers are currently doing. Such as recalibrating a machine once every (other) hour. Investing much money in that machine would replace those five minutes every (other) hour but it would not save a worker, as this person would do many other things next to it, does not sound appealing to management. That person does not require specialist, expensive repair work either. As the company needs a minimum number of workers to function, those workers can spend their downtime with small tasks that Industry 4.0 is to be taking over. That is what management has decided. In this company, Industry 4.0 is mostly used in tasks that require constant attention if done by hand and would be much more accurate if done with a computer. Such as the '*Proactive speed adjustment in the dough processing line'* as well as the wished '*Square cracker line straightener*' as well as the aspired new purchasing software that automates all the in- and output of the inventory and products.

For Company A there is another approach to implementing Industry 4.0. Most of the machines, such as their 3D-enhanced fish/meat cutter, their '*automatic satay skewer threader'* or enhanced refill stations function to deliver more precise work with fewer workers. Their main use is to optimize and therefore remove workforce. Company A is also focusing on reducing downtime and increasing safety with their machines.

One should note that Company B and Company C are American companies. For them, Industry 4.0 exists to work next to the regular employees, not replace them. For the European counterparts, Company A and their customers, Industry 4.0 technologies are used to deliver more work with fewer people and to decrease downtime, increasing efficiency and stabilize the workflow heavily.

7. CONCLUSION

Industry 4.0 is taking over big industries like food processing, sales, and the construction industry. The practical adaptive superiority of Industry 4.0 is most visible in the processing industry. After looking at the food processing industry, where bulk goods need to be repeatedly processed, where the flow of goods needs to be controlled, and downtime decreased, we see many uses for Industry 4.0. Many existing ones and many future ones, such as the *error management system* and *3D-enhanced cutters*. The main downside is the higher upfront investment in future-proof Industry 4.0. With short-sighted management, it frequently happens that investments are made for the solving of a single issue in the cheapest possible way what can save money within directly or soon. Whereas with Industry 4.0 it frequently pays out to invest more upfront for connectivity, for later linkage to the bigger system. Instead of costly readjustments, one would simply plug in a cable and link to the Cyber-Physical system. Company A has encouraged this by only selling, e.g., metal detectors with the LAN-port add-on. Together with breaking the shortsightedness of management by providing financing for Industry 4.0 and gaining back the money by taking the amount that the technology saved the company. This shows the critical initiatives that businesses need to have for Industry 4.0 to be taking a further dominant position in the world of manufacturing.

The size of the company matters for the easiness of implementing Industry 4.0 A small company might not need Industry 4.0 as a single manager can oversee the entire factory. Whereas with a big plant this is not possible. A big company like Company C can also invest much money due to its ability to withstand cost overruns. This in order to get others moving towards investing in Industry 4.0. Another reason is to help get rid of the teething problems of every new technology (wave). Thus, laying parts of the foundation for a new revolution. The fourth industrial revolution in relation to the industry, Industry 4.0.

8. CRITICISMS

The research is incomplete because only three companies who accepted an interview used Industry 4.0. And should thus should not lead to a (full) conclusion. Further research needs to take place in the field by interviewing more companies and possibly comparing that data to the data gathered in this thesis. The thought that American companies in food production are bigger than their European counterparts originates from the customers of Company A. It can only partially be backed up by data. The source (OECD, 2017) shows that the United States of America has a larger number of big companies than most European countries. One can say thus that 'large' companies in the United States of America are more prominent than in Europe. But Company A is specifically mentioning its customers, food production companies which are not mentioned in this source Data regarding this industry can be found in the paper of Wijnands & Verhoog (2016), where the 28 European Union countries are internally being compared. A comparison with the United States of America is executed as well. The United States of America turns out to have a higher competitiveness according to the paper, which could indicate bigger companies. The paper on its own is not enough to make the claim.

9. ACKNOWLEDGEMENTS

The foundation and inspiration for this paper was due to the work of my supervisor, H.H. Schiele. I would like to thank him for his feedback, support, and work in the field that defined my research.

The companies interviewed deserve gratitude. Without their insights, this research would not have been possible.

Special appreciation is given to my study advisor S.S Gritter-Spuls, for never giving up on me in the past years.

Recognition to A. Salač, N. Bortych, A. Kopyakova, T. Kern, B.F. Postema and my family for their ongoing support and feedback.

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11. APPENDIX A - GENERAL INTERVIEW QUESTIONS

Appendix A covers the interview questions used for interviewing the companies. In regards to the template used.

Intro:

1. Are you familiar with the concept of Industry 4.0, Also known as Cyber-Physical systems with machine-to-machine communication?
2. What are your expectations for this new industry? Do you see potential, or is this just a temporary and overhyped trend?

Retrieve cases:

3. Are you already using Industry 4.0 applications in your company?
    a. If so, could you give a few examples?
    b. How deeply implemented are/were they?
    c. Are some Industry 4.0 applications procurement-related?
    d. Do any of those projects involve suppliers? If yes, in which way? If no, do you see potential?
    e. Is your purchasing department involved in these projects to get Industry 4.0 in purchasing? With Industry 4.0 in mind, what is the process the purchasing department goes through to implement the technology?

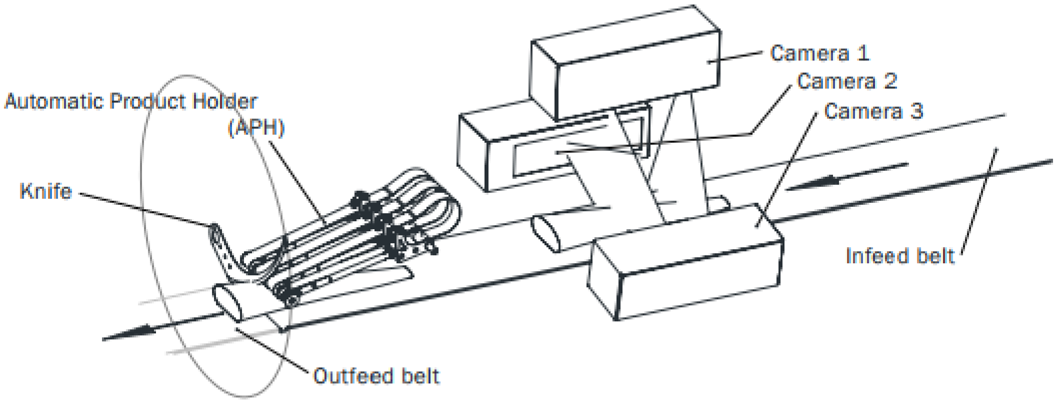
Past/partial/future:

4. Have you done any Industry 4.0 projects or machine-to-machine communication/Cyber-Physical systems in the past?

5. What applications of Industry 4.0 would you like to see in your company

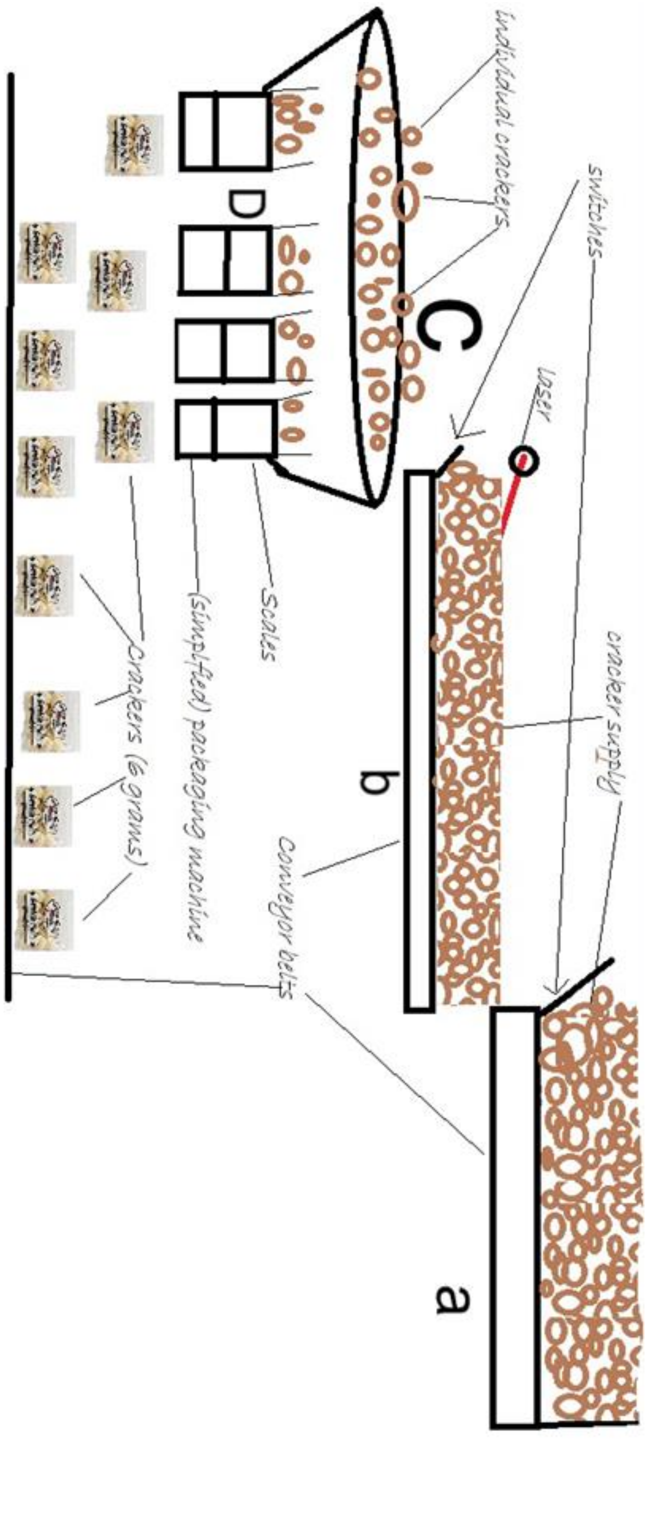
12. APPENDIX B - AUTOMATIC PRODUCT CUTTER

This picture provides an overview of the workings of the automatic product cutter/holder described in chapter 5.1.1 *example 3*. The picture was received by the owner of Company A while explaining *example 3* in the interview.



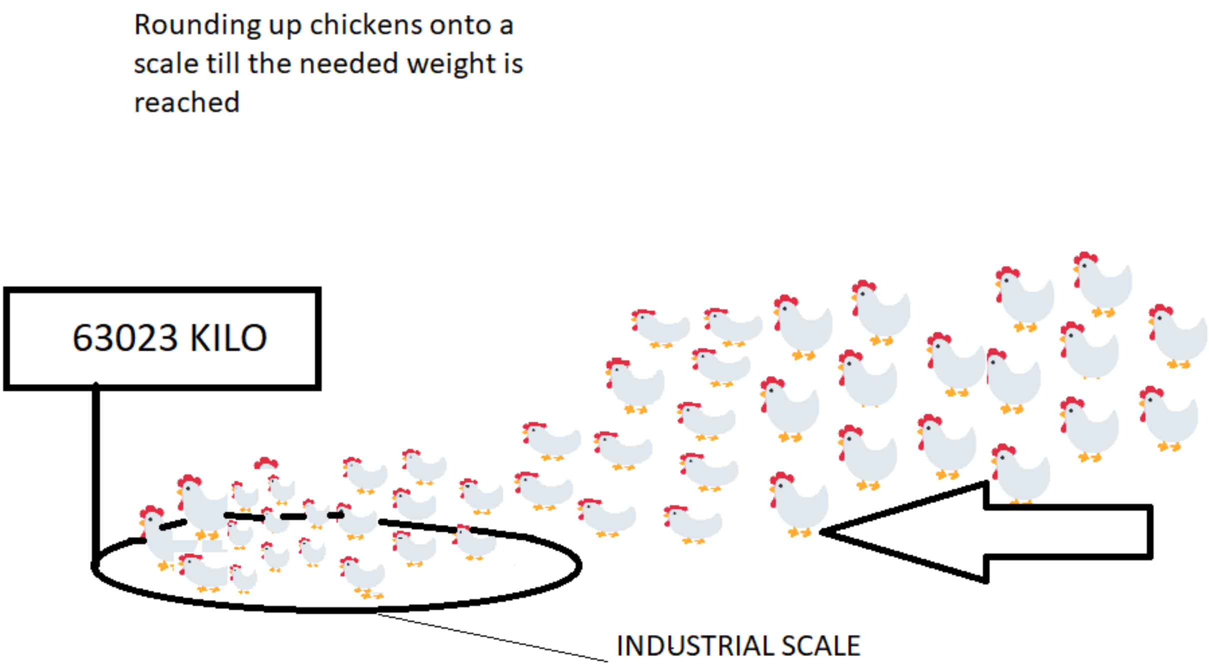
13. APPENDIX C - CRACKER WEIGHING SYSTEM

This picture is a simplistic overview of the cracker weighing system described in chapter 5.1.2 example 1.



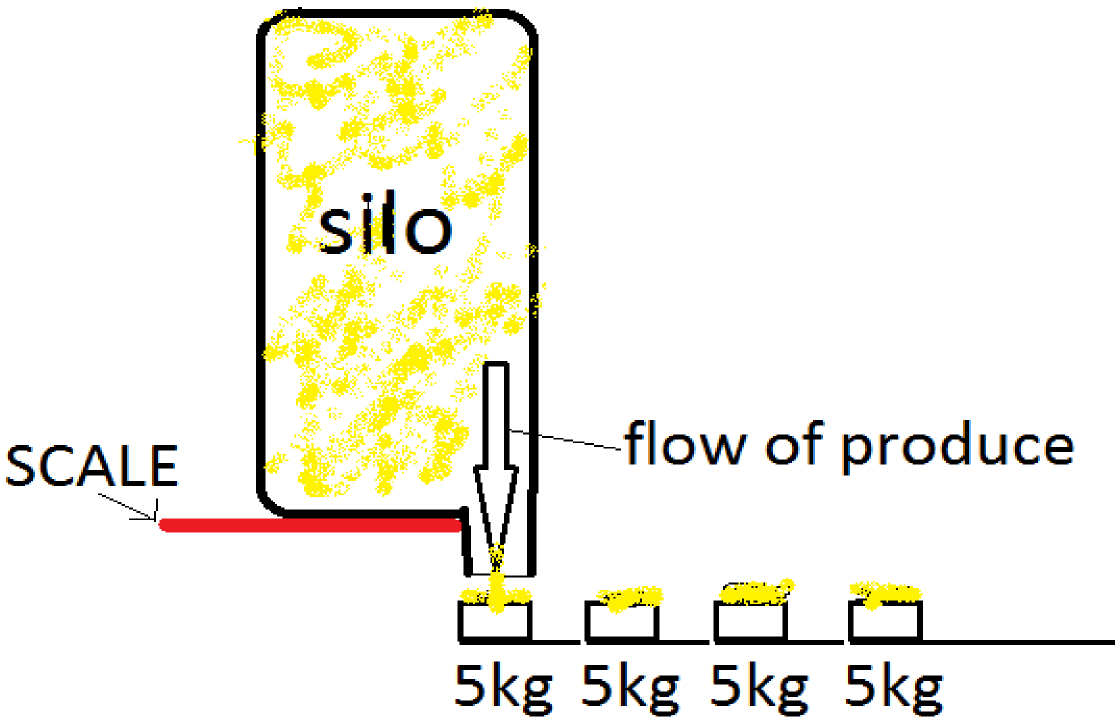
14. APPENDIX D - INDUSTRIAL CHICKEN SCALE

This picture is a simplistic overview of the industrial chicken scale described in chapter 5.2.1.1. Where chickens are rounded up and weighed until the needed weight is reached.



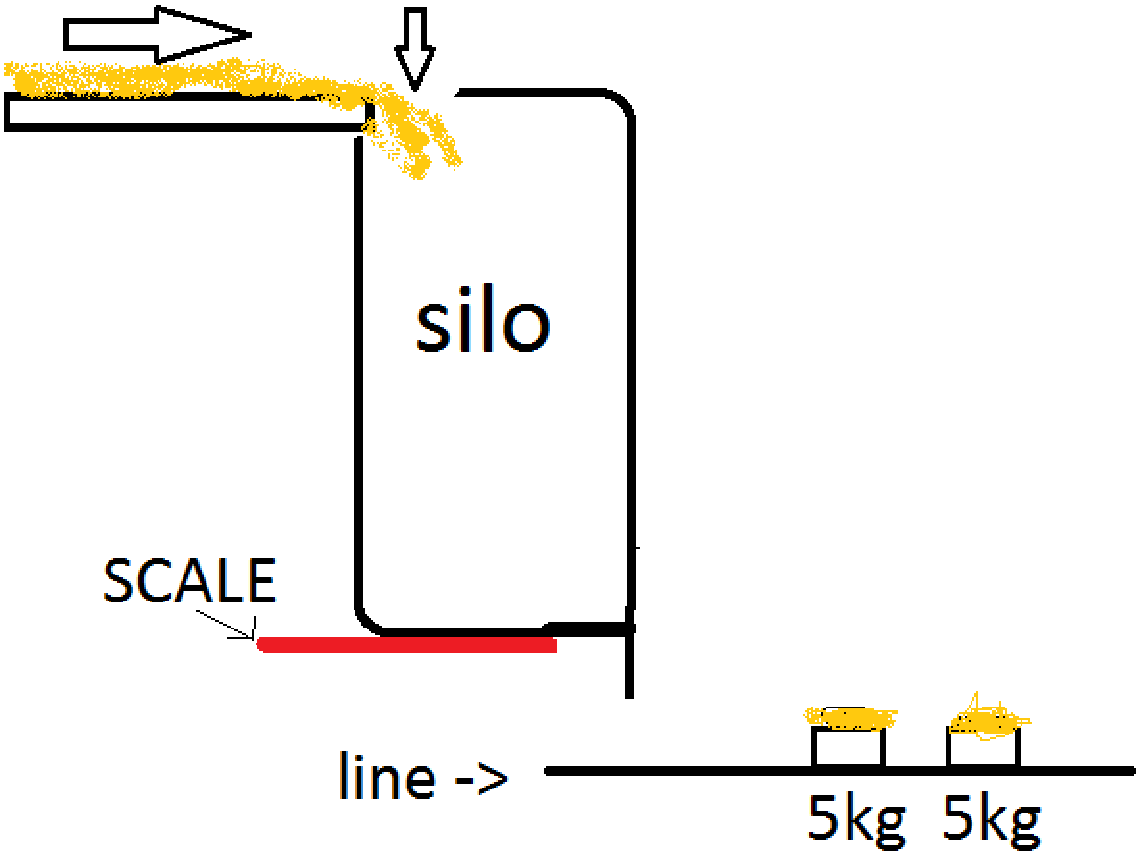
15. APPENDIX E - SILO DISPENSER

This appendix gives a simplistic overview of the silo dispenser that automatically detects if it is being refilled. The portrayed situation is that of the silo when it is dropping loads into the baskets and is not yet empty. It is mentioned in chapter 5.1.1 example 2.



16. APPENDIX F - SILO DISPENSER REFILL

This appendix gives a simplistic overview of the silo dispenser that automatically detects if it is being refilled. The portrayed situation is that of the silo when it has detected that it is empty and is currently being refilled. It stopped dropping loads into the baskets. It is mentioned in chapter 5.1.1 example 2.



17. APPENDIX G - AUTOMATICALLY SCALED MACHINE LOAD

This picture gives a simplistic overview of the workings of the proposed Industry 4.0 application mentioned in chapter 5.2.2. It portrays the automatic up and down scaling of machine load whenever a problem arises.