A report on the manufacturing industries in Sweden and Japan

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Content

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1 Summary

Manufacturing provides an important institutional foundation for learning and developing process skills, and enterprises which have capabilities that are intertwined with research are most important to the country's economic growth. Hence benchmarking some of the manufacturing best practices from industries around the world would help in identifying improvement opportunities and create a competitive environment within the organization. The main purpose of the PhD course "International Production" is to bring out the manufacturing practices from various industries globally and to provide an extensive report of the on-going methods. A group of PhD students from various Swedish universities visited some of the leading manufacturing companies in Sweden and Japan, to provide a comparative study of the manufacturing styles employed in the two countries based on the following focus areas:

- Digitalization and Industry 4.0
- Key Performance Indicators and Sustainability
- Quality Assurance and Integrated Product and Production Development
- Research Integration/Institutes
- Production Processes

This report provides a detailed explanation of the similarities and differences in the manufacturing companies between the two countries. With 23 PhD students and 17 industrial visits (both national and international), this overview report aims to provide a guideline for strategists and engineers in manufacturing planning and development. This course is a part of Produktion2030, a strategic innovation program supported by VINNOVA (Swedish Energy Agency and Formas). We would like to thank VINNOVA Strategic Vehicle Research and Innovation (FFI), Sustainable Production Programme and VINNOVA Production2030 Strategic Innovation Area for funding this course.

2 Sammanfattning på svenska

2.1 Introduktion

Kursen International Produktion är finansierad av VINNOVA genom Produktion 2030 och FFI samt stödd av Svenska Produktion Akademien, som består av framstående forskare och doktorander inom produktionsrelaterade områden. Kursen ämnar att öka färdigheterna kring globalt arbete hos blivande doktorer inom produkt- och produktionsutvecklingsområdet. Kursen har genomförts vid flera tillfällen tidigare, bland annat med resor till Kina, Italien, Brasilien, Indien med flera. Vid detta kurstillfälle hamnade fokus på Japan med en resa i mars 2018. Japan är känt för lean produktion och generell effektivitet, två positiva koncept. Högteknologisk produktion, unik kultur och kraftiga påverkningar av geografiska aspekter är andra kännetecken för Japan.

2.2 Bakgrund

Japans folkmängd är cirka 127 miljoner, medan Sveriges dito är kring 10 miljoner. Japans land area är ungefär 378 000 km2 gentemot Sveriges 447 000 km2. Således har Japan en mycket högre befolkningstäthet än Sverige, vilket påverkar många faktorer kring hur produktion kan och bör utformas. Till skillnad från Sverige så är Japan en isolerad ö-grupp utan fastlandsförbindelser, vilket även det påverkar produktionsmöjligheterna.

2.3 Kursdetaljer

Deltagarna i kursen bestod av 23 doktorander från sju olika svenska lärosäten, ledda av två seniora forskare - professor Bengt-Göran Rosén från Högskolan i Halmstad, och professor Lihui Wang från Kungliga Tekniska Högskolan.
Syftet och målet med kursen fokuserar huvudsakligen på den framtida förbättringen av svensk industri genom utnyttjandet av kunskap från andra länder. Kursen har fyra huvudmål:

- Att bättre förstå svensk industri
- Att bättre förstå japansk industri
- Att öka kunskapen och förståelsen av produktion i allmänhet
- Att förbättra svensk industri i framtiden genom att sprida kunskapen och förståelsen genom blivande doktorer inom området.

2.4 Studiebesök

Totalt så gjordes 20 studiebesök under kursens gång, var och en utförd på varierande sätt beroende på vad mottagande part kunde erbjuda. Vissa besök var en guidad tur i fabriken, medan andra innefattade presentationer, turer, diskussionsgrupper med mera. Utav de 20 studiebesöken var 17 industriföretag, sex svenska och 11 japanska, och tre lärosäten – Keio University, University of Nagoya, och Tokyo University.

2.5 Fokusområden

Då kursteamet bestod av doktorander med olika industrirelaterade expertisområden delades doktoranderna in i fem olika grupper. Varje grupp hade ett eget fokusområde som de studerade under kursens gång; kvalitetssäkring inom integrerad produkt- och produktionsutveckling, digitalisering och Industri 4.0, produktionsprocesser, KPIer och hållbarhet, samt samarbete mellan forskning och industri.

2.6 Resultat och diskussion

En jämförelse mellan japanska och svenska leverantörers perspektiv gällande prioriteringar av olika nyckelområden inom kvalitetssäkring inom integrerad produkt- och produktionsutveckling gav följande utfall: Flexibilitet inom produktionssystem, problemspårning, funktionstestning, samt kvalitetsrevisioner var alla ungefär lika viktiga i båda länderna. Realtidsanalys av kvalitet, statistisk processkontroll, och synkronisering av kvalitetsledningssystem med underleverantörer var ansedda som mer viktiga av de japanska leverantörerna jämfört med de svenska.

Gällande digitalisering och Industri 4.0 identifierades likheter och skillnader länderna emellan som presenteras i tabellen nedan.

Likheter	Olikheter
Svårigheter att attrahera unga arbetare	Japanska företag använder förebyggande underhåll för kunders utrustning
Konservativa IT-avdelningar som inte strävar efter Industri 4.0	Svenska företag samarbetar mycket mer med akademin
Siktar på hög Industri 4.0-mognad, men är en bit därifrån	Datavisualisering användes mer i Japan
Företag inser vikten av bättre informations- och kontrollnivåer	Japanska företag följer upp prestation på en individnivå, vilket är sällsynt i Sverige
Använder kanban-system för datavisualisering	

När det kommer till produktionsprocesser så specialiserade sig båda länderna på högteknologisk produktion, dock är svensk industri mer influerad av japansk produktionsfilosofi än tvärtom. Av de besökta företagen i båda länderna så var visuell inspektion mycket mer framträdande i Japan. Båda länderna lägger mycket vikt på återvinning av hushållsprodukter men har något olika sätt att se till att gamla produkter återvinns på rätt sätt. Språkkunskaper gjorde det svårare för Japanska företag att samarbeta internationellt, vilket kan leda till missade möjligheter.

Runt KPIer så fokuserade svenska företag mer på kvalitet, energiförbrukning och säkerhet medan japanska företag hade mer fokus på dagliga produktionsmål och arbetarnas kunskapsnivå. I Japan presenterades mycket av informationen på papper, medan motsvarande i Sverige var digitalt på skärmar. Svenska företag lade mycket fokus på kvalitetskontroll av den färdiga produkten, medan japanska företag förlitade sig mycket mer på kontinuerlig kvalitetskontroll.

Vad gäller hållbarhet så syntes ett större fokus på samhällets engagemang i industri och tillverkning i Japan, till exempel så fanns det program för utveckling av ungdomar, stöd för funktionsnedsatta, och program för skolungdomar hos tillverkande företag. Det var också vanligt att studenter och lokala invånare gick på fabriksrundturer, samt praktiska aktiviteter som marknadsförde både kommersiell och miljörelaterad medvetenhet. I Sverige syntes inte motsvarande lika tydligt, utan där drivs snarare studiebesök och dylikt av akademin snarare än industrin. Istället ligger mer tyngd på studenter som redan inriktat sig mot industri.

De huvudsakliga resultaten runt samarbetet mellan forskning och industri var att båda länderna håller forskning i högt beaktande, och driver en väldigt kundorienterad forskning. Dock är forskning i Japan utfört av specialister separat från industrin, medan det i Sverige är mer vanligt att med korsfunktionella team som samarbetar med industri. En högre grad av kundmedverkan i forskningen var framträdande i Sverige, medan en mer dynamisk interaktion mellan leverantör och partner syntes i Japan. Det var också mycket vanligare med samarbeta mellan forskning och industri i Sverige.

3 Background

The population of Japan is roughly 127 million, while Sweden's is around 10 million. The nation of Japan covers approximately 378 000 km2, while Sweden covers roughly 447 000 km2. This means that Japan has a much higher density of population, which affects many factors of how production could and should be performed. Sweden is located on the mainland, connected directly to both Norway and Finland, while Japan is an isolated group of islands in the Pacific Ocean.

4 Purpose, research questions and method

4.1 Purpose

The course International Production is funded by VINNOVA through the Swedish strategic innovation initiative Production 2030 and supported by the Swedish Production Academy, which consists of leaders and PhD students conducting production-related research and providing production-related education at Swedish universities. The course aims to increase the skills of the coming PhDs in production and product development to work successfully for their companies and universities on a global arena. Previous versions of this course have included visits to China, Italy, Brazil, eastern Europe, and India. The latest edition of the course completed the final part of four with a visit to Japan in March 2018, a country known for lean production and efficiency in general. Japan is not only one of the world leaders when it comes to the production of high-tech products but also known for its unique culture and is heavily influenced by geological prerequisites.

4.2 Course details

The course team consisted of 23 PhD Students from 7 Swedish universities and two senior researchers, professor Bengt-Göran Rosén from Halmstad University, and professor Lihui

Wang from KTH Royal Institute of Technology. The course team can be seen in the picture on the front page.

4.3 Method

As the course team consisted of PhD students who are experts in various areas of industry-related research, a division of the students were performed to maximize the knowledge yield of the course. This led to five focus areas which were studied during the course; quality assurance within integrated product and production, digitalization and Industry 4.0, production processes, KPIs and sustainability, and research in manufacturing. Companies in Sweden and Japan were visited and the officials, managers, representatives and CEOs of respective companies were interviewed based on the focus groups. Based on the observations, discussions and with some reference of articles a detailed description is presented from each of these focus areas along with their findings in the form of a report.

5 Objective

5.1 Aim and purpose of the course

The aim and purpose of the course are mainly focused on the improvement of Swedish industry in the future by making use of knowledge gained from abroad. The four main objectives are:

- To learn more about the Swedish industry
- To learn more about the Japanese industry
- To increase the knowledge and understanding of production in general
- To improve Swedish industry in the future by spreading the knowledge and understanding via upcoming PhDs graduates.

6 Results and deliverables

6.1 Quality assurance within integrated product and production development

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Quality Assurance (QA) can be defined as the operations and procedures that are conducted to supply measurement data on predefined quality conditions. This means that quality assurance includes all the activities conducted throughout the product development phases that are directed to ensure the product quality [1]. Integrated product and production development refer to the condition of integrating the activities and the decision making processes during the product development phase that affects the ability to achieve efficient and effective production [2]. Considering these definitions, in this section, the focus will be on the operations that are conducted during the decision making and development processes to provide measurement data for satisfying the quality requirements. In the following sections, a summary of the observations within the Swedish industry and within the Japanese industry is presented. Later, observations from the respective country are compared to each other and evaluated. Finally, some of the main challenges to achieving a well-functioning mechanism are identified and discussed.

In the Japanese culture, it is common to get a lifetime employment, i.e. to work for the same company from the graduation of studies until retirement. This makes employees acquire a high technical knowledge on the company's products, production processes and thus, quality. In addition, the commitment, loyalty and discipline of employees to their companies are high. Employees are not just working for a company; instead, they feel they work for their company. It is a matter of reputation, which encourage them to do their best in their daily job resulting in high-quality results. However, limiting the professional career to a single company can lead to tedious and boring tasks and unawareness of improvements in other companies which can hinder the company progress.

In Japan, quality assurance is integrated into the company philosophy and thus it is embedded in every step of the product realization process. During the production process, quality is ensured by every employee at every step. Therefore, there is no need to follow specific quality improvement programs, such as Six Sigma (which commonly is applied in western companies), because the quality actions are inherent to their production processes.

Experienced employees with a special education on quality assurance are considered as "Masters" and represented with Golden Cards, which could have a similarity to "black belts" in Six Sigma. "Masters" level is obtained by a long process that combines experience, exam results, acquisition of certificates and specific goal achievements. However, every employee is encouraged to suggest quality improvements and they all work under the culture of “Kaizen”, what in Europe is named as continuous improvement, inherited from the Japanese term.

In addition, quality assurance in Japanese companies can also be a consequence of the high production control. Every step of the process is controlled and expressed as indicators, for example, the control of the production environment is done by monitoring factors such as temperature, humidity and dust-level, the process time and synchronization and the status of the machines in ambition to ensure a successful production. Every factor is measured and recorded, and every product has a check chart. In-process control and visualization of production status in real time are also common approaches. This, together with the connectivity enhanced from the advantages of the implementation of Industry 4.0, allows the generation of large amounts of data about the status and control of every product and process. Strategies on how to utilize big data efficiently for process improvements and Quality Assurance are now under examination.

Production and quality departments are normally working together. Quality department is working with production problems and customer claims. Claims are registered in the system, evaluated and solved by a qualified team to ensure continuous improvements. Japan has a strong technology development. Companies invest together with universities in research development, innovation and production. It is common that companies have design development and production facilities located in the same areas of the country, which enables a more integrated product and production development. Similarities to Sweden can be seen in this matter.

The work culture in Sweden is more dynamic in the sense that a worker expects to work for different companies along the professional career. This gives better interdisciplinary knowledge. However, the loyalty and commitment can be lower than in Japan and can thus, affect quality improvements.

In Sweden, Six Sigma is commonly implemented, and many companies currently put resources into education in Six Sigma and apply the methodologies in activities for continuous improvements. Companies currently not posing Six Sigma activities have still presented desires to implement these. In Sweden, the pressure to implement philosophies like this is arising from the outside. The difference to Japan is that a term called “Six Sigma” is not outspoken to be a part of the company philosophy. And as already mentioned, the difference here is not that Japan doesn’t work with continuous improvements regarding quality assurance but rather, that it is strongly grounded in the culture and thus, is a matter of routines.

In Sweden, the production is normally monitored by visible charts, which play a key part during production meetings. Generally, production meetings are regularly organized as an aim of informing employers with production related issues regarding status, problems, delays, and so forth. Production and quality departments are normally working together. Quality department is working with production problems, claims, and quality of the products. Claims are registered in the system, evaluated and solved by qualified teams to enable continuous improvements by putting focus primarily on recurrences of specific claims or problems.

Quality assurance and integrated product and production have a wide definition in Swedish and Japanese production culture. It can regard implementation of Six Sigma, customer-based measurement, inspection based on industrial standards, using quality control charts for both inspection and quality control. These strategies are selected mainly based on the type of product and production volume. Therefore, in the following sections, an analysis based on different production volumes and complexities is presented.

6.1.1 Products composed of complex systems and low volume

6.1.1.1 Sweden

Quality measures are mainly defined by customer needs. Having specific quality criteria for a specific customer is a method applied in industries with limited customer range. This apparently fulfils the quality assurance activities but hinders the availability of development ideas. Feeding the development ideas upstream to the product might attract the customers and make the supplier outstanding compared to his competitive counterpart. While the downstream development or developing based on customer needs might make the label flexible, but over time might build a reputation for lack of competence. For developing the product based on customer needs, modular, flexible and adjustable product architecture is required. Whereas in production, having a flexible production system to adapt to the changes derived from the customer needs might be a challenge to achieve. The risk of having higher costs for constant changes in the production processes is another factor that should be considered.

This type of industry works with continuous improvement by implementing quality tools such as Six Sigma. The product development and manufacturing collaborate from the early stages. One of the advantages of low volume production with respect to quality measures is the possibility of inspection of a high percentage of products. However, lack of reusing measurement data and production data hinders statistical analysis to feedback data and information for research and development.

These companies generally have a dedicated team/department that focuses on recommended objectives to improve the product and production. These recommendations are accepted from all factions; customers, operators, managers or any other person who could contribute with their ideas.

It is always challenging for small-scale production companies to compete with large-scale producers in terms of production cost. Hence, companies focus on producing customized products with high quality and efficiency with best technical support.

6.1.1.2 Japan

Several companies within the category of complex products with a low-volume production were visited. Many of these companies were machine and tool builders. Several commonalities with regards to the product quality and quality assurance were identified among them.

The most apparent characteristic in this category was highly flexible and modular products, which made the production systems quite similar to each other. Several job shops in the shop floor made the production system more flexible. This can be regarded as the production flexibility. The existence of the check sheets during the whole production for the specific products, including the customer's information, their specification and the specifically required processes was observed as decision making support regarding quality assurance. The combination of the process, product and production flexibility and the relation between them are affecting the quality assurance activities. Having customer-based quality criteria and in-process control for checking the accuracy of the machines in production and the products is the main driver for the quality assurance activities. To summarize the activities of and flows between the several flexibilities within the integrated product and production systems, see Figure 1.

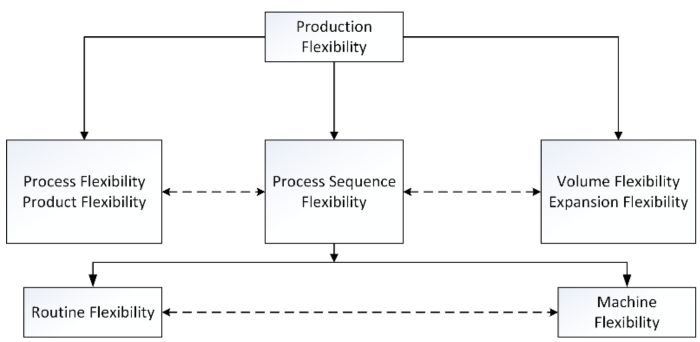


FIGURE 1 FLEXIBILITIES AND THEIR RELATION [3]

Data-driven production was applied within the visited companies. Taking advantage of the new trends of big data handling, cyber-physical manufacturing systems is an enabler for a more accurate and real-time quality check and optimization of the processes and the products towards pre-defined customer-based quality criteria. One of the preconditions of developing such systems is automation, when applicable. In this category as well as generally within technology development, the Japanese industry was quite advanced. Taking advantage of the latest machines, systems and tools, i.e. automated visual quality control cameras and scanners is a demonstrator for these efforts. Another enabler towards a more digitalized quality control was a fully automated maintenance system for quality check during aftermarket of the products. Simulations were used heavily for production and product improvements. At the organizational level, there exists a quality control department, dedicated only to the quality matters. During the in-process control, in case of a problem occurs, the quality department will be notified and with cooperation with the production department, the quality issues will be resolved.

Due to the strict quality demands of some products, specifically high precision products or from specific customers, the production environment was under heavy control. Temperature control, humidity control, usage of air shower passes, air vacuums were widespread to assure precision and quality of the final products.

6.1.1.3 Comparison

In general, it can be stated that the quality control activities performed in this category are quite similar to the ones performed in Sweden. However, as mentioned above taking advantage of a more in-process control and real-time quality check was one of the main difference. This also goes back to the culture and philosophy of the companies and their mindset towards quality control within a highly integrated environment, in terms of product and production.

6.1.2 Products composed of complex systems and high volume

In this category companies that are producing a complex system at a high rate and volume are considered. Complex system regards products that have at least dozens of assemblies and different production process are applied during their production. Cars, pumps and machines are some examples of these products.

6.1.2.1 Sweden

These companies usually centralize laboratories for quality inspection. Quality is mainly assessed at the initial stage of production and the final product. The production system is usually fully automated with monitored checkpoints at different stages of production. These industries present high-quality customization.

Industries, related to the production of raw material, has a distinct quality measure for every product/batch, which is an attribute of these types of industries. Strict quality measures are a requirement in this type of industry with high production volume to avoid batch rejection. One of the advantages in metal alloy industry is that the development of the products is solely limited to the raw material. This type of industry is less multi-disciplinary compared to other Original Equipment Manufacturers for instance. Therefore quality assurance activities rarely hinder the development process, especially production development.

6.1.2.2 Japan

The visited companies that produce complex systems in a high volume were mostly car industries. Some of these companies use the concept of a Digital Twin in production for quality control. For instance, in the assembly of a product, they have a model of the product in the computer. The model is shown to the operators in monitors and each process performed on the real assembly will be applied to its Digital Twin. That makes monitoring of the quality of the assembly very easy because it can be seen on the computer model. For example, all bolts that are assembled by enough torque are receiving a green colour in the computer model, the twin of the product and thus, the operators know that enough torque has been applied for a product with high quality.

The production lines consist of dozens of stations and each person in each station should make sure about the quality visually as much as it is possible. Additionally, in Japan some dedicated employees known as “white helmets”, has the prioritized task to resolve problems at stations where deviations occur. In the end, the main quality checks such as measuring dimensions and checking functions are done mainly on the final product, though.

Some of these industries use First Time Through (FTT) or First Time Right (FTR) system as a measure of the production quality and efficiency. These are measured as combinations of; total parts, good parts and scrap parts. The ratio of good parts to total parts will give the FTT rate. The first time through yield will help you identify efficiency and changes in performance in the production process and should be used as a signal to perform further analysis and improvements if it exhibits sudden big changes.

6.1.2.3 Comparison

Considering these types of industries, in both Sweden and Japan, production processes and quality control are automated and are done mostly by robots. However, in Japan manual work is existing for quality control and assembly of more sensitive and precise sections. As far as it can be concluded from the visits they are not familiar with Six Sigma-system in Japan, not that they don’t work with similar philosophies but rather, that they don’t label anything “Six Sigma”, when on the other hand in Sweden it is important to brand the company as working with Six Sigma. Another finding and a bit rough conclusion can be that technicians and operators are working with quality to a larger extent in Japan than what these specific individuals do in Sweden. However, since the visits were limited to just two or three industries of this type in each country, generalizing the conclusion and comparison should be considered as rough results and be used cautiously.

6.1.3 Suppliers

Good quality means quality which is produced with the maximum use of the manufacturer's existing capability such as production, engineering and process capability to meet consumer needs[4]. This approach towards product quality has led to reduced defects, increased reliability with low cost, reduced rework and wastage, lower inspection and testing times, and high productivity. The global manufacturing industry is increasingly concerned with the quality of the products received from their suppliers which affect the supply chain management, quality standards, lead time and thus productivity. Some of the challenges faced by manufacturers to maintain the quality of outsourced products include visibility, traceability, identifying errors, flexibility in manufacturing systems, reporting, conformance and compliance. These challenges are generally dealt with focus on supplier quality management by introducing the manufacturer’s quality management systems to the supplier, real-time quality analysis, problem tracking, pay-back for poor quality, streamlined corrective measures and supplier quality audits [5].

6.1.3.1 Sweden

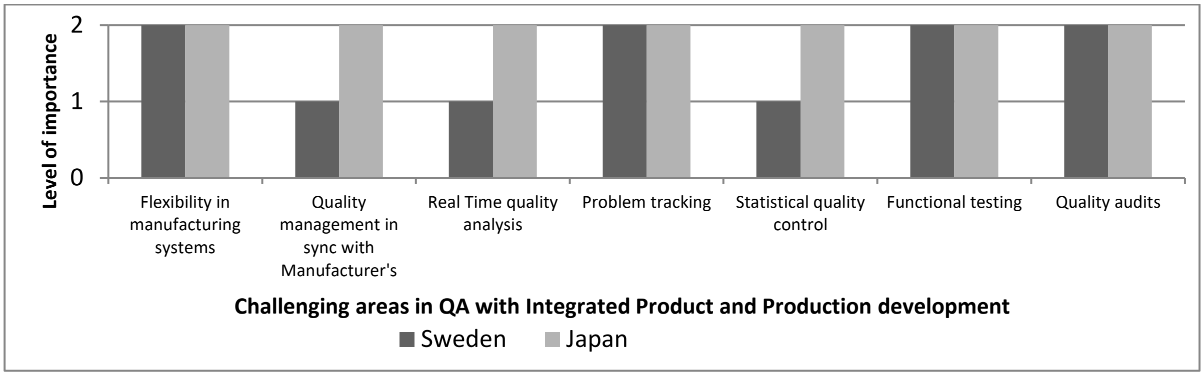
There has been an increasing interest in measuring customer satisfaction on a national scale in order to promote quality and make the industry more competitive and market-oriented [6]. Quality assurance with respect to suppliers' perspective implies complying with the rules and standards. The manufacturing is more focused on the quality inspection and process control. Flexible manufacturing systems are adapted in the production lines for product variety and aims for continuous improvement of product and processes. Quality inspection are generally done once every certain number of parts. However, the use of statistical process control (SPC) or control charts to evaluate their manufacturing process performances is rather low. Measurement data is only utilized to evaluate the defects rates and not for quality assurance. Regarding the assessment of quality at early stages of the product realization process, companies use simulation to evaluate the product quality performance but it does not use simulations to evaluate the manufacturing process performance.

6.1.3.2 Japan

Japanese industries, well known for producing quality products, generally choose suppliers within the country for a good reason of being very reliable. In most cases, quality management system adopted by the Japanese suppliers is analogous with the manufacturer's quality standards. The manufacturing systems are flexible to adapt for product variety and modularization. Production includes advanced process monitoring and quality inspection to ensure product quality meets the specifications and standards. Additionally, functional tests are conducted on critical parts in centralized laboratories. Data obtained from inspection and functional testing are statistically analyzed and used to develop control charts. The inspection data are further used for product and process improvement. In Japan, statistical quality control is used in a broader perspective as company-wide quality control (CWQC) where quality refers to not only the product quality but also quality management, after-sales service, company as a whole and human being [4]. The suppliers are potentially aiming to visualize and utilize the acquired data in every step to increase the product and production value.

6.1.3.3 Comparison

Figure 2 presents a comparison between Japanese and Swedish suppliers' perspective on the importance of key areas in quality assurance with integrated product and production development.



Disclaimer: The stats are based on the observations from company visits in Sweden and Japan.

FIGURE 2 CHALLENGING AREAS IN QA WITH INTEGRATED PRODUCT AND PRODUCTION DEVELOPMENT

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6.2 Digitalization and Industry 4.0

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6.2.1 Digitalization

The production and internal logistics in manufacturing and warehousing companies, more specifically the order picking for distribution or assembly could be divided into manual and mechanized/automated with different levels of automation (LoA). The same can be done for quality and verification, where the functional attributes of the final products are verified. A taxonomy developed by Frohm (2008) is used to measure the cognitive (information and control) and physical (mechanical and equipment) levels. The taxonomy consists of seven different LoA, ranging from totally manual (level 1) to totally automatic (level 7).

6.2.2 Industry 4.0

The data visualization is of significant importance to the manufacturing process. The real-time manufacturing data sensing, processing, sharing, and exchanging service is the core of the manufacturing information visualization within Industry 4.0 (Zhang et al., 2016). Traditionally, human and industrial robots are working separately in time or space due to safety concerns. Human-robot collaboration (HRC) is a concept that industrial robot works alongside the human worker who jointly performs the assigned tasks. In the HRC system, the human worker can assign dull, dirty or dangerous tasks to the industrial robot. The industrial robot can give real-time feedback to the human worker. By combining the advantages from both the human worker and industrial robot, HRC has the potential to achieve higher productivity and better sustainability for modern factories.

Machine learning is a major enabler in HRC and Industry 4.0. One of the main applications of Machine learning in HRC is recognizing human worker’s motion and assembly objects on the workstation. With this information available, it is possible to know how to effectively assist the human operator, e.g. when to pass what tools or parts to the human operator to improve the productivity of the HRC system while maintaining safety (Lenz, 2011). There have been reported studies on recognizing and understanding the motions of human (Roitberg et al, 2014; Perez-D’Arpino and Shah, 2015; Hasan and Abdul-Kareem, 2014). Another machine learning application example in Industry 4.0 is predictive maintenance. With large amounts of historical data, compared with traditional empirical approaches, statistical machine learning approaches can be applied to increase prediction accuracy. For instance, Li (Li et al., 2014) provided an example of transportation system maintenance by applying machine learning algorithms.

6.2.2.1 Industry 4.0 Maturity Index

As introduced in Schuh's index (Schuh et al., 2017), there are two different stages of digital transformation: digitalization and Industry 4.0. The digitalization stage solves data computerization and connectivity issues, while Industry 4.0 solves visibility, transparency, predictively, and adaptability issues. In traditional manufacturing companies, many of the issues still remain. Due to integration difficulties and market acceptability, many of the concepts actually cannot find a profitable business case in traditional manufacturing companies. However, due to different cultures and rapid development concepts, in Internet companies, many (perhaps all) the above-addressed issues are solved a long time ago. With more and more digital-based disruptive technologies, the traditional manufacturing industry should be adapted to the digitalization and Industry 4.0 in the future.

6.2.3 Sweden

6.2.3.1 Logistics

The used equipment for orders fulfilling and the level of automation in the studied companies varies. Regarding the physical automation of internal logistics, the majority of companies use man on board picker to parts systems utilizing forklifts. However, taking into consideration the differences in the products physical characteristics, some companies used cranes for transporting large and heavy weight items. According to Frohm (2008) companies have a 4 or 5 physical LoA. Regarding the information and control automation, some companies use totally manual information systems, where the actions are taken based on the operator's own experience and understanding of the situation. For example, refilling the materials, and picking the required amount of the needed items from the warehouse storage only happens based on the operator´s realization of the need for it. Accordingly, for the previously described cases, the cognitive automation is considered to be 1. Other companies are using slightly higher cognitive automation levels reaching level 2, with the decision giving LoA, where for example pick to voice systems are used to help the operator locating the right material, in the right place, with the right quantity**.**

6.2.3.2 Production

Concerning human operators in the visited factories, the levels of automation vary greatly between the physical (LoA_p) and cognitive (LoA_c) aspects, for the various work tasks in the manufacturing processes. Work instructions and other work-related information for most assembly work were observed to be primarily disseminated through word by mouth or through paper, occasionally with pictures. The production information is also difficult to understand without the specific prerequisite knowledge and requires long training periods. Hence, the levels of cognitive automation at the various visited factories are relatively low, around level 2 due to that the cognitive automation helps the human operator making decisions, but it is not a teaching system. On the other hand, many of the visited factories have quite specialized machines that the humans operate, which renders a relatively higher level of physical automation, at level 5. However, since the flexible human operators in factories manage a variety of tasks surrounding the value-adding activities, the range of level of automation for different work activities extend between levels 1-2 for cognitive level of automation and 1-5 for physical level of automation.

Among the visited factories, the process industries are outliers with higher level of physical automation, closer to level 6, and its cognitive level of automation around levels 5-6 since most operators intervene when something unexpected occurs (LoA_c=6), but human operators do manually tour the factory to monitor what the production system cannot do itself (LoA_c=5).

6.2.3.3 Quality and verification

Having a closer look at the end of line operations for verification of functional attributes of products, with a focus on physical automation of the tasks, different levels of automation can be observed. In general, there is a high potential for increasing the level of automation for end of line verification in visited companies.

For instance, a visited heavy machinery manufacturer with a range of highly customized products had a low level of automation between level 2 and 3. Indeed, highly customized products lead to a lower level of automation when it comes to end of line sign-offs. For comparison, another manufacturer that mainly produces automotive parts had both types of mass-produced products and customized services and products. For customized products, the company's LoA for end of line quality verification can be graded similarly to the heavy machinery manufacturer. But, the company has a higher level of automation for mass-produced products, between 3 to 5 for different products.

6.2.3.4 Industry 4.0

6.2.3.4.1 Maintenance

From the maintenance perspective, the development with the respect to the maturity index differs both between the companies, but also within the companies. In general, companies are not yet using prediction and self-optimization of the equipment (maturity index 5 and 6) but are closer to step 3 and 4. Many companies are storing data such as failure time, failure reason etc., but it is not visualized. One of the visited companies has invested in much digital technology for maintenance purposes, to start visualizing and understand why deviations, failures, and quality issues appear. It is a small company, with owners that are really interested in new technology, leading to the maintenance manager being allowed to invest in new technology in line with Industry 4.0 and use resources for the maintenance application. This company has started to build competence in visualizing and understanding (maturity index 3 and 4) their data internally. In another company, there were a mix of very old machines and relatively new ones. The old ones are not even connected. The new machines are connected to the machine supplier, and the data is visualized for the machine supplier. For these new machines, the maintenance is on contract. The contract includes a yearly service, but also service and measures suggestions depending on what is happening in the machine – which is visualized in the data and interpreted with their experience to also understand why. Here, the competence is built externally. But there is also some competence built internally regarding visualizing data. For some important bearings, condition-monitoring equipment for vibration has been installed, which is used to see the development of vibration, to be able to schedule preventive maintenance. But when a failure occurs, troubleshooting is done based on experience instead of visualized data. Even though some of the companies are touching upon maturity index 4, there is still work to do to fully reach that stage. Visualizing and analyzing data can explain some of the events explained to start to build an understanding of why. But there are still events that not can be explained, and therefore something to work more on.

6.2.3.4.2 Machine learning and human-robot collaboration

None of the visited companies applied machine learning, unfortunately. However, many of the companies already started to apply collaborative robots. For example, two Swedish companies started to test UR collaborative robots on the production line to explore the possibility to let human and robot working at the same assembly station.

One Swedish company applied an interesting approach to not use robots during assembly. Their products have a huge variation compared with other companies. Therefore, the product can be largely customized, and the operators need to spend a long time to learn the whole assembly process. In this way, the company intentionally make the assembly process challenging and interesting for workers, so they will not quit. The whole assembly process is finished in the same workstation, workers need 8-10 weeks to learn the whole assembly process. In this case, no robot currently can help and handle the complexity of the assembly process. Perhaps the company's local community ownership also encouraged the way of working.

Sweden put a lot of effort into smart digitalization. The bigger the company the more resources it put on developing IT-structures with stand-alone systems and central databases. To be able to reach the higher level in smart automation, Swedish R&D focuses on developing of Cyber-Physical Systems where all products, machines, and humans are integrated. The digital strategies, therefore, focus on decentralization, interoperability and reducing complexity. The governmental support helps the small and the middle range companies to keep up with the development.

6.2.3.4.3 Data visualization

From the perspective of data visualization, the manufacturing companies we visit show the growing interest in the data processing for the manufacturing process, like the assembly and production. Due to some factors, some of the manufacturing companies did not apply the techniques and tools of data visualization in the manufacturing shop floors. The high cost of the techniques and tools for data visualization applied in the manufacturing process is a main factor. In addition, the managers of the companies considered that there is no demand for data visualization for the traditional manufacturing companies such as the production of the gears.

The data visualization in the manufacturing companies, in particular, the large-sized manufacturing companies, is applied in the production and assembly of components. The manufacturing process is visualized by the digital interface like the Kanban system. In the digital interface, the production schedule, machining status of components, the status of machines and workers, the information of production plan and execution, and the production exceptions are visualized and monitored in real time. This can contribute to supporting the decision-making of managers and improving the efficiency of production. However, the applications of data visualization in the manufacturing companies are at the primary level. Some of them are used to display the digitalization level of manufacturing companies, not serve the real production of companies. In addition, the added value of data and data mining for the manufacturing process are not deployed in the manufacturing companies.

6.2.3.4.4 Data value chain - making data available and visible

For all companies visited, none of them expressed any strategy of using big data or data to drive their decision-making. The awareness of concepts like Industry 4.0 also varied between the companies, which suggest that most of them do not have a strategy aligned with it. It was not clearly expressed what their ambitions were related to connecting their production e.g. with more sensors for collecting data about their process and thereby also now more about their processes. Most companies were computerized and had data presented at visual boards or dashboards with KPI's to follow up their production goals. All large and medium enterprises were at least at a level 1 with computerization. None of them really reached a level of 4 where the data collected is transparent for the organization and can drive the decision-making. Level 2, connectivity, mostly involved a connection to internal information systems, e.g. to ERP and MES. There were no mobile connections. The few existing connections were stationary for machines or production cells. Level 3, visibility of data, was present to some extent in most medium to large sized enterprises. A lot of the production data were visualized, either at the machine/production cells or at digital dashboard visualizing production data, mainly KPI's. One of the companies used paper and pen to document for each individual production step, so no digitalized information of what the machine operators followed up on a daily/weekly basis. Another company had control rooms where the processes were monitored and controlled with real-time data. For level 4, transparency, it was not explained how real-time data can be or are used. For one of the companies, a current challenge is to get a better supporting information system to facilitate the planning process. The forecast of the demand is difficult to predict and it is desired to have better information from the customer to enable better planning horizon. One of the companies stressed that they would like to transform into an organization/business that will rely more heavily on data from their process when making decisions. It is an extensive work and change for the organization, but they have realized the need of driving their decisions based on better and more data. Sharing of data was mentioned at the two companies that are material suppliers. The customers share their data and they can, therefore, gain a lot of knowledge and information from the customers that will enhance their product.

6.2.4 Japan

6.2.4.1 Logistics

The order picking equipment and levels of automation in internal logistics varies slightly in the visited companies in Japan. Physical automation is achieved using man on board picker to parts systems for large size items, and automated guided vehicles (AGV) for smaller items, with a physical automation level of 4 and 5. Regarding the information and control automation, some companies have totally manual systems with paper-based picking systems which place them at LoA of 1. However, most companies have higher LoA which is 2, where they utilize decision giving systems such as pick to light to help the operator in picking the right items and quantities. The automation level inside the warehouses is considerably lower than between the production and warehouse (internal logistics), where the warehouses are run by mainly manual systems.

One faced challenge in Japanese companies is the resilience of employees to using higher levels of information and control in picking system, which could be referred to the employee's age and dependence on experience.

6.2.4.2 Production

The physical levels of automation (LoA_p) for the human operators in most of the visited Japanese factories vary depending on specific work tasks. Small components were sometimes assembled manually by hand (LoA_p=1) and sometimes using a static hand tool (LoA_p=2) or a flexible hand tool (LoA_p=3). For larger components lifting cranes and other more automatic tools (LoA_p=4 and 5) supported the operators. However, even more physically automatic support tools for assembly work were rare at the visited industries in Japan. Nevertheless, the physical levels of automation in this final assembly type of factories are quite similar to their Swedish counterparts. Comparing to the assembly systems in India (Bokrantz et al., 2017), both Sweden and Japan are slightly more physically automated, stretching from level 1 to 5, while India varies between levels 1 and 3.

Most information about the products is dependent on printed paper and word-by-mouth to be shared among the human operators. Even though some of the visited factories in Japan have made some efforts to implement video instructions, these were still at an experimental phase, not widely implemented. However, the central part regarding providing sufficient cognitive support for human operators, the information on printed paper are simply not work instructions, and the workers rely on their training and experience to understand the work tasks. Hence, for most work, LoA_c=1, even though few instances of LoA_c=3 exists, similar to India (Bokrantz et al., 2017), and slightly lower than assembly in Sweden (mostly LoA_c=2). However, representatives from visited Japanese factories attribute their reduced need of LoA_c to their more extensive and rigorous training of new operators. Since most employees in Japan work for their employers for a long period of time, often entire careers, the investment cost of training is easier to motivate.

6.2.4.3 Quality and verification

In general, the Japanese manufacturing industry is very well oriented towards implementing automation in different phases of product and production development. In terms of physical verification of requirements, different levels of automation were observed. The *LoA* varies between 2 to 7, in different phases of production and in different industries. For example, a visited automotive manufacturer of heavy vehicles had a LoA of 2-3 for end of line verification for the final product, while a part manufacturer had a 100%

automated verification both for part verification and final product verification (*LoA*=7). Interestingly, one of the visited heavy tools manufacturers, had a high level of automation (*LoA*=5) for product verification, although it produces highly customized products.

6.2.4.4 Industry 4.0

6.2.4.4.1 Maintenance

In Japan, many companies within machining and tooling were visited. Many of these companies were working to collect data from their customer's machines, in order to learn more about the machines. However, there are some resistant from the customer, as they are not willing to let external people access their data bases. One of the companies has therefore developed a certain "box", where they can access the customer's data without entering their internal network. The same company are aiming to work with AI and predictive maintenance (maturity index 5 and 6), and have created a team dedicated to work with development. However, a comment from the company was "it is much deeper than we thought". An interesting highlight for these company is that they mainly wanted to work with predictive maintenance for their customer, secondly in their own production. An explanation of this could be the change in business model, where the machine is more as a "service" than a product.

The visited companies within the automotive industry, have started to collect data, such as vibration and temperature for maintenance purposes (maturity index 3 and 4). However, all companies aiming to work with predictive maintenance have just started, and work with it mainly internally (no/little support from academia). The major way of conduct maintenance is still time-based (for example every week, every month). For example, one company start the shift with maintenance tasks received from their maintenance system, where a schedule has been manually created. As a complement to the time-based maintenance, condition monitoring systems are used with more critical equipment. In some companies, the machines were very old and did not support condition monitoring at all.

A challenge that the companies are facing is to attract the right competence for AI and predictive maintenance. In general, Japan has an ageing population, and it is difficult as to get young people to the industry. More specific, it is even more difficult to make people from data and computer domain interested in working in the industry.

6.2.4.4.2 Machine learning and human-robot collaboration

During the Japan visit, none of the companies directly applied HRC. Machine tool companies, for instance, DMG Mori, MAZAK, and Makino mostly using human assembly due to the complex assembly process. While many of the companies have the potential to adopt HRC in the future. Automobile manufacturers such as UD track, Toyota, and Mitsubishi have the potential to apply HRC in the sub-assembly process which currently heavily relies on manual work. Companies such as Denso, Kyoto tool, and Asahi beer are already automated most of the assembly process. Those companies are producing smaller and simpler products compared with the aforementioned machine tool companies and automobile manufacturers.

The application of machine learning is still in the earlier stage for most of the visited companies. However, many companies have the plan to apply machine learning. The most common potential application for machine learning is predictive maintenance. Some of the machine tool companies also developed a more systematic approach towards data acquisition and connection. Thus, there is more potential for the companies and customers to explore machine learning applications.

The shift from mass production to mass customization requires significant changes in information management and computerization of all phases in the production chain. Integrated digital systems that exchange information between production plants, service supply and the end users are required. Most of the Japanese companies recognize these needs, but they are far from its realization. In some companies, they started the data collection but do not have the clear vision of how all these data could be integrated and used.

6.2.4.4.3 Data visualization

Many manufacturing companies we visited in Japan consider the data visualization very important, especially in the machine tool and automobile manufacturing companies. The data visualization has been widely used in the production, scheduling, assembly, inventory, and logistics for these companies. It can be concluded that the Japanese manufacturing companies have good work experience and techniques for data visualization. Advanced technologies such as the Internet of Things, RFID technology, and Cloud technology are used to collect data from the manufacturing workshop, machines, and inventory. Then, the collected data are visualized in several forms to display through the interface. The data from a specific machining to the whole factory production are displayed to operators and managers, for example, the spindle analytics and Dashboard of factories. To monitor and manage the production process in real time, the information viewer by mobile devices is also achieved for some machining devices. The successful and effective data visualization developed by the Japanese manufacturing companies can improve the efficiency of production, and contribute to helping workers and managers to make good decisions in changing the production plans and monitoring the exceptions in workshops.

However, the data visualization is developed and ran in the internal of manufacturing factories or the workshops. It still has difficulties in collecting data from machines or devices sold to customers. This limits company managers to acquire the operating information, and further, affect the improvement in design and manufacturing of machines. In addition, data from specific devices cannot be visualized because of the special structure of these devices, and no interface.

6.2.4.4.4 Data value chain - making data available and visible

Concepts like Industry 4.0, Internet of Things, and smart manufacturing were encountered during the visits to the Japanese companies. An awareness existed, and some companies stressed it a lot when it comes to the solutions that they provide to their customers. During the study trip, many machine tool builders were visited, and they could demonstrate a history of solutions and examples that are very much aligned to what is now considered as smart manufacturing, using sensor data from the machines. Applications and examples from the same concepts, however, was not as present in the workshop, or at least not demonstrated. One of the company visited could demonstrate how they are making it visible for everyone what assembly station that is occupied and if the order is according to plan or delayed. In this way, a real-time feedback can be visualized about the production status and it could even be tracked on an individual level, the assembler. Other examples of how data in combination with ICT was used in the production to support the operator in their work, was in the kitting and material handling department. This was an automated process where the operator used a bracelet to tick off the material picked and a light system supported the operator to know where to pick. This was seen in the companies within the automotive industry. To relate to the different stages in the Industry 4.0 Maturity Index, most companies where computerized. One reflection of the lean concepts, that were encountered at almost all of the companies visited, is that it depends a lot on things not being digital. The main idea is to use notes and other aids that can support to make problems visible in the workshop. The connectivity level was mentioned at some of the companies, especially one of the machine tool builders that provide a solution for connecting machines over Ethernet and Wi-Fi. It was, however, not explained or really demonstrated in the workshop so it was difficult to understand the functionalities. Visibility of data existed, mainly with dashboards visualizing production status. This was seen at all companies, and some of them have gone further in making real-time visualization of their machines. Transparency of data existed, for example, what was explained with real-time visualization of occupation and status of the assemblers work.

6.2.4.5 Comparison between Sweden and Japan

6.2.4.5.1 Similarities

Concerning digitalization and Industry 4.0, certain challenges that both Japan and Sweden are facing have similar characteristics. Large companies in both countries have quite conservative IT departments that are protective of their data, which inhibits external collaboration, for example; difficulties in building a connection between companies and customers in accessing data, lack of standard of data visualization for different companies, and data from some key devices cannot be visualized. However, within the production networks, information sharing is currently enabled by IT systems with an Industry 4.0 maturity index close to stages 3 and 4, at least for critical equipment. But there is a common aim to reach stages 5 and 6 in a near future. Examples of current Industry 4.0 practice are; use of Kanban systems for data visualization, and work with a maintenance system for management of work orders and scheduling.

For internal logistics, more precisely order picking and fulfilment, the importance of having higher information and control automation levels are recognized. At the same time, there are difficulties identifying the right physical level of automation and its tradeoffs with flexibility. Concerning the shop-floor operators, both countries have similar levels of physical automation as physical ergonomics support, mostly manual varying between LoA_p=1-5.

On a grander scheme, the current digitalization and Industry 4.0 development is closely linked to challenges of demographic changes in both countries. With ageing populations, perhaps more pronounced in Japan, new digitalization and Industry 4.0 enabling technologies have the possibility to help attract future workforce to the manufacturing industries.

6.2.4.5.2 Differences

Despite many similarities in the areas of industrial digitalization and Industry 4.0, there exist some distinctive differences between the two countries. Japanese manufacturing companies tend to place greater importance in data visualization and processing compared to Swedish counterparts. The better use of data visualization improves production performance and monitors manufacturing processes. This information management is also evident in the Japanese interest in predictive maintenance of customers' equipment. Although it is quite common in Sweden as well, it is not considered important enough for implementation in own production systems.

Among the visited companies, verification activities are more automated in Japan compared to Sweden, especially when it comes to high rate master production. However, for shop-floor operators with assembly work, level of cognitive automation for supporting operators is reversed. While Japanese operators take more pride in learning by heart, Swedish operators are following written instructions to a greater extent. However, this cognitive support is anyhow quite low, not exceeding $LoA_c=1$ in Japan and $LoA_c=2$ in Sweden. On the other hand, companies in Japan are tracking operator's performance on an individual level with the motivation of understanding efficiency by each individual, which is rare in Sweden.

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6.3 Production processes

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All industrial manufacturing is composed of one or several different production processes. Each process can be optimized with regards to several different factors. How well these production processes are optimized, individually and as a production system, corresponds to the productivity and efficiency of the factory or company.

Depending on several factors specific to different areas in the world, as shown in figure 3, processes need to be optimized with regards to different factors. If the salary cost in one country is low the incitement to invest in highly automated processes is likely to be lower compared the same production process located in a region with high salary cost.

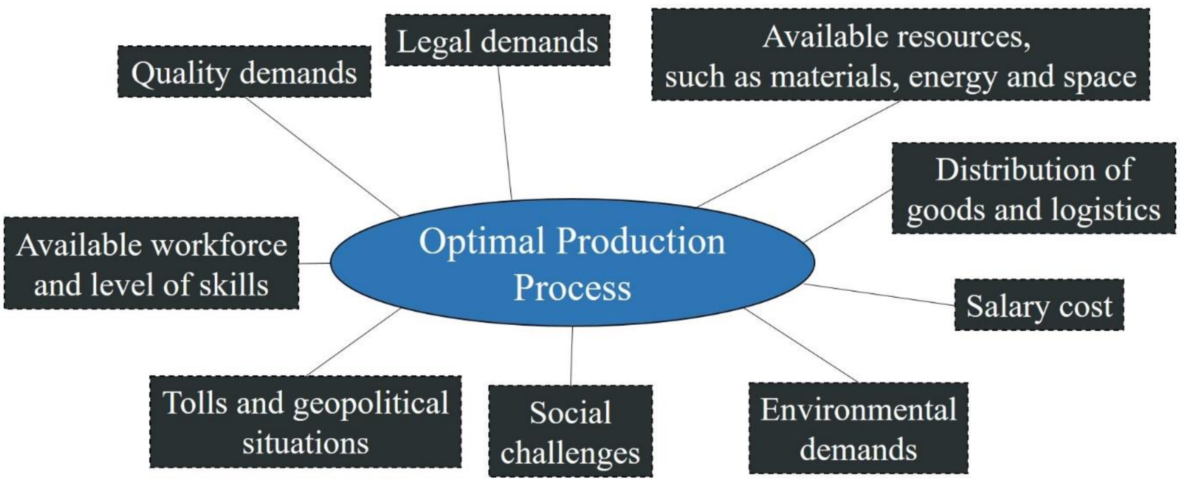

FIGURE 3 FACTORS INFLUENCING THE OPTIMIZATION OF A PRODUCTION PROCESS, MODIFIED AFTER JOHANSSON ET AL. [1].

Japan has had a great influence on the production processes in the world in terms of LEAN production according to the Toyota way, which relates to Figure 1 regarding quality, resources and total cost. In Sweden, many of the big companies have implemented LEAN manufacturing to some extent.

All over the world, environmental issues are becoming more prioritized. In the manufacturing industry, it is also important to continuously work with environmental issues within the production because of regular increase of the environmental and legal demands, both on a national but also on more regional levels, such as demands implemented by the European Union. The choice of manufacturing processes and methods oftentimes have a large impact on the total environmental footprint of a product during its lifetime. Therefore, it is of great importance to see how manufacturing processes are optimized and compare differences and similarities between choices of processes in the Swedish and Japanese manufacturing industry.

6.3.1 Sweden

The industry in Sweden has in many cases gone from a labour-intensive to a more automated production in which higher salary costs is one of the driving factors. Higher salary costs connect to the need of skilled workforce with higher education because of the automated production process. This is a potential social challenge for the future when many of the easier jobs are automated. A trend for all visited companies is that due to a lack of skilled workforce more effort is put into optimization and development of automated production processes.

From the industry visits in Sweden, the work with environmental issues could be seen in different aspects depending on the category of industry. In industries which were processing raw material, the recycled material was commonly used to process new raw material for further manufacturing. The importance of quality of the new material was prioritized as the material was tested and analyzed in an early stage in the process.

In manufacturing companies, which was processing finished components, it was more of importance to have tools which were optimized for the production process. In a company which had several CNC machines in the production, tool cost can be a major expense, by optimizing the tools used and cutting parameters there are possibilities to decrease the manufacturing cost. It was also seen that recycling of cutting fluid and material e.g. recycling of chips from the manufacturing and used cutting tools is important in an environmental aspect but also to decrease the total costs of production.

In all companies visited there was co-operation with Universities or research institutes in different projects to some extent. This trend will probably increase in the future to optimize the production and the quality of the product to increase the competitiveness of the company on a global market. At this time, SME-companies which traditionally have not had any experience to co-operate with the academy, now have to develop its production in terms of automation and digitalization when the production machines and other equipment are more advanced compared to only 5 – 10 years ago.

6.3.2 Japan

Japan is one of the most industrialized countries in the world and has very strong traditions regarding industrial production and manufacturing. Some of the world’s largest manufacturing companies are founded in Japan such as Toyota, Sony and Mitsui. Japanese manufacturing philosophy and management has largely influenced western manufacturing industry with for instance implementation of lean manufacturing.

Japan does not have very much space since it is heavy populated islands with a lot of uninhabitable mountains making space a highly valued resource. Production requires space and in some of the visited factories, the lack of space was evident especially for newly built production sites. In addition, buildings and structures in Japan must be built to withstand earthquakes, it is crucial to have a stable ground for large machines and precision machining when manufacturing complex components.

The demographic situation in Japan is troublesome with an ageing and diminishing population. This and a diminished interest in the traditional manufacturing industry has made it difficult for companies to recruit suitable personnel. In response to this, automation is widely used to reduce the number of operators. It is not common to change employer many times during the working career, especially not for shop floor operators and technology specialists. Some of the visited companies even had lifetime contracts for some of the employees. This gives employees the opportunity to be highly qualified for the work with long experience and the employer is very keen to provide a stimulating workplace and possibilities for operators to move inside the company. The experienced workers help the companies to maintain a high productivity and it is common with learner programs for new personnel where the more experienced workers educate the newly employed.

Work skills and experience seems to be highly valued in the visited companies. This was very evident in one of the visited companies that are producing milling machines and other machine tools. When manufacturing the bed for the machine tool the planarity and surfaces structure is very important in the company this was done manually by scraping. The operator performing the scraping had to do a three years learner program before working in the production line making them very valuable to the company. Another company, manufacturing similar machine tools, had found a way to replace the manual scraping with milling. The reason for replacing the manual process with an automated milling operation was to make the results more repeatable and faster, and the company claimed that it also helped in reducing friction making the machine more energy efficient, but it is not unreasonable to speculate one of the reasons for replacing the manual process was a lack of qualified personnel. The manufacturing of a CNC machine is of high complexity and precision, especially in the spindle manufacturing which puts a high demand on a controlled and clean environment in the assembly process. The production flow in the spindle assembly was easier to overview compared to many other production flows in the same factory. In general, it was hard to find a consistent material flow of the production which could be explained by the size of the components and machines produced. A general impression of the factory floor was unorganized and less utilization of factory floor space compared to the automotive industry. One of the companies have tried different layouts of the warehouse, at first, they had higher racks but now they had small racks and storage on the ground, this to get a better overview of the stocks of parts. The downside of this layout is less utilization of space, messy impression and more movement of different pallets to access parts.

As the LEAN production concept according to the Toyota way was introduced in Japan, many of the companies visited in Japan have implemented or have been influenced by LEAN within their production. Particularly in the companies visited connected to the car industry the LEAN concept was noticed within the production. These companies have a high degree of automation from welding to trains delivering and replenishing parts to the assembly line. The utilization of the factory floor is well optimized and the transportation of the cars and trucks are made in the ceiling. Many of the suppliers, to the car companies, are located within 1-2 hours from the factory to minimize downtime within the production. Depending on the production, the inspection of the finished product could be different. Small components which were mass produced could be inspected by cameras. However, inspections of a complete car were often done visually in a separate step in the assembly process by a trained quality controller. To ensure the quality in picking parts for assembly one company had a system of which lights indicated which parts to be picked and before putting the parts on the train for delivery a probe had to be touched to indicate that the part had been picked. One of the suppliers to the automotive industry had a very high degree of automation, they also had a height limit of 1.4 m of all their production lines to get a better visual overview when the production indicates a problem.

Today it is common to outsource simple production processes to low salary countries. One of the companies visited was a tool manufacturer, the production was symbolized with old machines and low automation level compared to the rest of the companies visited. Many of the different production steps could easily be outsourced to low salary countries but the manufacturer took pride in having their tools made in Japan compared to many other tool manufacturers. The quality of the tools is seen as in the upper level by the customers compared to many competitors.

6.3.3 Comparison between Sweden and Japan

Japan has traditionally been a very closed culture with few outside influences. The country was closed to the outside world until 1854. Even today it is difficult to communicate in English or any other language than Japanese which was noted throughout the visits.

In general, there is not so great differences between Sweden and Japan regarding production processes and the implementation of technology in production. In both countries, most of the observed production can be described as high tech production. Swedish industry is probably more inspired by its Japanese counterpart than the other way around. Although there was one example of how the Swedish way of production was implemented in the companies visited in Japan that had been acquired by a Swedish company. After the takeover there had been a change in the production, this was especially noted in the new production line which had been built. The automation level was higher compared to before and the noise level was lower, this due to the use of noise reduction tools. The longtime goal was to implement the same model in the rest of the factory in the future. Even though the new production line had been influenced from the Swedish owner, the visual inspections were still high compared to the same production in Sweden.

In terms of environmental issues and recycling of used wastes from household, when buying a new machine for your household e.g. dishwasher or television in Japan you pay an extra fee for future recycling. In comparison to Sweden, it is free of charge to bring your old used household machines for recycling. Both Sweden and Japan put effort in education campaigns in recycling and environmental issues. It is common to invite school kids and the public to different recycling facilities to show the importance of recycling and how the process is performed. In Japan where the manufacturers of different household products have their own recycling plants, it is possible to have a feedback loop from the recycling plant to the design department of how the products can be designed to ease the recycling process.

6.3.4 References

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6.4 Key Performance Indicators and Sustainability

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6.4.1 Key Performance Indicators

Key Performance Indicators (KPIs) are used in almost every company today in order to monitor and control the production processes, goals, costs, and to make sure decisions and improvement projects are in line with the company's strategy [1]. In the following part, the description and analysis of KPIs in Sweden and Japan as part of the study trip of the course International Production of the Production 2010 Graduate School are presented. Moreover, a comparative analysis is also presented after the description of KPIs used in Swedish and Japanese companies.

6.4.1.1 Sweden

The studied companies can be divided into three groups when it comes to their use of KPIs, low automation level, high automation level, and small companies. The first group is compound by the companies with a significant number of manual processes and operators working at the shop floor. In one of the visits a comment was mentioned by the guide about performing manual manufacturing processes: sometimes it can be like cooking Bolognese pasta, it is not easy to every time obtain exactly the same product results.

All the companies in this group use lean inspired visual management boards for their daily production control and management. However, the reality of the obtained data in this kind of companies with mostly manual processes can be heavily altered by using different data collection methods or procedures and different people implementing them. Hence, one always has to ask if the KPIs are right and what are the key issues to obtain and represent the data from the measurements [2]. Common for these whiteboards is that they show indicators for quality, usually defects or complaints, delivery reliability, often in terms of produced products in relation to the planned products, and availability of different resources (both machines and operators). There was often information about current improvement work and the status of different project visualised closely to the KPI boards. One of the companies also had safety indicators in terms of the number of incidents. Additionally, clear indications of possible potential accidents and risks were shown in several production cells and machines along the shop floor. They also had digital boards which show the status of the process in real time. The most common KPI visualised on these digital boards is OEE (Overall Equipment Efficiency) which is a combined indicator of quality, utilization and availability. The digital boards also show the three components of OEE individually. In some cases, there were one or few dedicated areas to show KPIs in centralized parts or rooms of the shop floor. The information shown in these locations was usually on whiteboards and usually gathered different team members every morning (area responsible, production managers, operators…) and they usually focus on quality, service level, electricity consumption, and production materials.

The second group is the factories with a high level of automation of their production with very few operators working on the shop floor. In these companies, the production control is handled from control rooms in which the status of the process was visualized on computer screens. They also had whiteboards with more long-term indicators in the control rooms. In some of the stations in the factory, information was displayed on whiteboards, e.g. the current price of the raw material which was used to help the operators optimize the material cost. In another factory, a daily visual management board was found in the manual packing station which was the only station where operators were working at the shop floor. In some cases, the KPIs data of two or three product articles per production cell is analyzed (having around five or six production cells); the rest of KPIs shown on screens are customized for the different products and individual machines. KPIs are usually used as a base for bottom-up improvement approaches. At least two of the companies visited use Axxos as a communication platform to show the KPIs on different screens on the shop floor. Usually product quality and accidents play a big role in the analysis of KPIs in this kind of companies; additionally, KPIs as throughput, work in progress, and lead time was closely monitored.

The third group is a small company with only 11 employees. This company have one whiteboard for information where they had their production planning and competence matrix visualized. They had the possibility to collect production data in real time but they do not use it today.

6.4.1.2 Japan

The studied Japanese companies used KPIs in a similar way. Japanese companies use different kinds of boards for information and KPIs in their production. Most of the non-digital boards were full of spreadsheets and very few charts could be seen. However, most of the companies had digital boards with no of produced parts and target for the day in their factories. The digital boards were supported by status lights on most of the stations in the production process that in a very visual way indicated if the machine or station was running smoothly (green), having problems in finishing the parts on time (yellow) or standing still (red). This gives the team leaders a good overview of the process right now and in which stations they might need help.

Some of the companies used more advanced real-time monitoring of their machines which showed the status of the machine during the day. This was shown on screens with a timeline with different colour codes for the different statuses a machine could have. However, it was not the most common case.

Quality is the most important thing in most of the companies in production. However, very few quality measures were found in the production area since the quality is built-in in the process by having manual quality control stations; if any quality deviation is found, the line is immediately stopped. Therefore the measure of the number of produced parts includes the quality performance of the process. However, some of the companies also stated that they use statistical tools for quality work which means that they have some kind of monitoring the quality performance even though it was not clearly displayed on the shop floor.

In Japan, it is important for the workers to achieve high skill-levels in their work and this was clearly visualized in the factories. Many of the companies had a wall close to the entrance of the factory where all the employees that had certification of the government were listed together with their degree, the higher level of certification the higher up on the list the employee was located.

Another interesting finding is that when some of the companies were asked what their next step towards Industry 4.0 is, they all answered “how to use the data”, which indicates that the focus is shifting from performance measurement and monitoring to performance management.

6.4.1.3 Comparison Key Performance Indicators

Several companies were analyzed in the country of the rising sun. The majority of them in the automotive and machine-tool sectors. In the case of Sweden, the majority of companies visited were in goods manufacturing such as agricultural machinery, water pumps, and gears and gearboxes. However, all the companies can be considered under the umbrella of the manufacturing sector, having in common similar aims and objectives for the improvement of their production systems, usually based on KPIs.

KPIs are usually quantitatively used for assessing manufacturing performance in the industry [3]. In many cases, they are used as a reference for system improvement and as a tool to measure production. They can be considered as routine measurements of manufacturing planning and control effectiveness and used for auditing and benchmark purposes [2]. Due to the characteristics of most of the companies visited and analyzed in both countries, this comparison focuses on mid- and big size companies (considered as companies with more than 250 employees).

As mentioned before, Swedish mid- and big-size companies usually use lean inspired visual management boards for their daily production control and management, often presented on monitors or screens distributed along the shop floor or centralized in the same room somewhere on the shop floor. On the other hand, regarding the Japanese case, in most of the companies analyzed, the use of lean inspired visual management boards was also usually integrated into daily production. However, surprisingly, a general impression of high-tech electronics was absent on the shop floor. In most of the cases, instead, the use of pen and paper information boards with collected data from the daily production was used. They high-tech electronic devices were usually presented in the showrooms of the factories, to present the products and production to potential customers and visitors.

Besides it, without considering how the data of KPIs was presented on the shop floor, in most of the Swedish and Japanese cases, there was a primary KPI, this is throughput or produced parts. This throughput was usually shown per hour, per day, per week, per month, or per year, depending on the production volume of the manufacturer (having lead times ranging from 2.5s to 2 weeks). In some of the Japanese companies, this throughput value was sometimes substituted by a “line moving speed” value, to measure productivity. The line moving speed is how fast the products are moving in the production line, usually measured in meters per minute. The line speed can usually be adapted depending on the amount of manpower working at the line at every moment and the demand. The working stations and tools of the different operations move together with the products of the line, at the same speed, on something they called “magic carpet”. These magic carpets are platforms moving on both sides of the lines at the same speed as the products. On those platforms, the operators are able to work with the products. After the station or operation is finished, the platforms go back quickly to the original position (beginning of the operation for the next product coming in the line). The material was usually delivered to the line by AGVs that were able to follow the specific products or magic carpet at a coordinated speed. A high line moving speed means lack of failures or stops in the production line and high throughput.

Regarding the KPI of quality control of products, there is a major difference between Swedish and Japanese companies. In Japan a so-called “check man” position was utilized. In most of the cases of companies visited in Japan, the quality control measurement process is done repetitively between processes. Hence, every time a product goes to the next process, both in machining and assembly, there is a manual inspection of the product in which the check man follows a checklist (sometimes (rarely), this inspection was performed automatically). However, in Swedish companies, the weight of the quality KPIs was considerably more relevant at the end of the production process, measuring the quality of finished goods. A general impression at the Swedish companies was that their KPIs for quality, defects, complaints, and delivery reliability were noticeable emphasized on the boards or screen on the shop floor. However, at the Japanese companies, these KPIs did not have so much presence on the shop floor, mainly due to the general policy of not accepting or allowing a product to keep being processed in the production line without the required quality.

Ideally, in the Japanese system, the Swedish standard of quality measures of finished products would not be necessary, since a product which does not achieve the quality requirements, cannot continue its production process in the production line. Usually, the line is stopped, the product removed, and an analysis to solve the root of the problem started. This system can be more effective to avoid wasting time and production capacity on a product that will be rejected at the final goods quality control; or even worst, producing products with quality failures that may pass unnoticed the final quality control. On the other hand, this system with intermediate quality controls after every operation can have a significant cost if performed manually. That was the case in most of the Japanese cases. Other relevant KPIs to be compared related to electricity, electricity price and consumption. Even Though the prices of electricity are significantly higher in Japan (see Figure 4), another remarkable difference regarding KPIs in Sweden and Japan was the absence of electricity consumption measurements and raw-material prices on the shop floors in the second country. A reason for that could be that the variation of prices of materials in Europe due to the lack of suppliers might be more volatile, however, the price of electricity seems to be significantly more volatile in Japan than in Europe, especially due to the risk of natural catastrophes in the Nippon country.

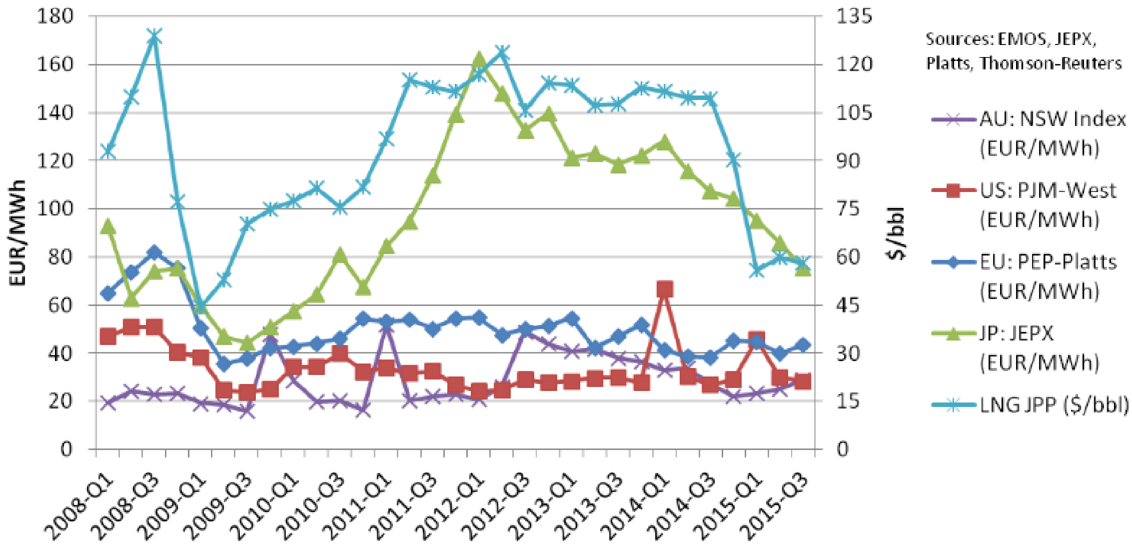

FIGURE 4 QUARTERLY AVERAGES OF BASE LOAD-TYPE PRICES ON THE ELECTRICITY MARKETS IN JAPAN, EU, THE US, AND AUSTRALIA. JAPANESE LIQUEFIED NATURAL GAS (LNG) IMPORT PRICE PROVIDED AS A REFERENCE [4].

To conclude, the use of KPIs is extendedly used in manufacturing industries in both countries, both on the shop floor and on a more strategic level for system improvement. However, in the Scandinavian country, there is an extensive focus on quality, electricity consumption, and accidents, something that in the Asiatic country seems to be absent, especially on the shop floor. On the other hand, in the Japanese factories usually there is a focus on target objectives for the day, especially regarding the amount of produced parts and finished products, and in workers' expertise and education, which was usually shown on whiteboards on the shop floor. KPIs such as throughput, work in progress, and lead time was commonly analyzed and summarized on the shop floor in both countries, mainly on screen in the Swedish factories, and on whiteboards or wall posters in the Japanese factories. Additionally, the method to collect this information was a mix of automatic data logging systems (such machines or cells connected to a central monitoring system like Axxos) and manual systems (noting the values collected manually on whiteboards and then introduced in a computer system). Nevertheless and with some exceptions, on the one hand, Sweden seems to use more commonly the first automated approach, while in Japan the second manual one. This is a clear advantage for Sweden to step up on digitalization and the tendency of Industry 4.0.

Another important aspect to highlight is the lack of focus in the number of deviations (both quality and other production stops) in Japan. As mentioned before, the main reason is the Japanese culture of solving problems when they occur, even if that means stopping the entire production. That is not a common case in Sweden, where usually the problems are solved afterwards without interrupting production and with more emphasis on quality control once the products are finished. However, it has the drawback of wasting time, resources, and production capacity on products that will be rejected at the end of the line due to lack of quality.

6.4.2 Sustainability

The most common definition of sustainable development is probably the Brundtland definition; "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [5]. The United Nations formulated a new 15-year goal on sustainable development, which covers for the period 2015-2030. However, achieving a sustainable development is so difficult that it cannot be left to the government alone, but it requires a very active participation of all the segments of society, including all the business and private sectors. With this in focus, all the industries across the globe claim to have sustainable development as one of the primary goals.

6.4.2.1 Sweden's approach towards sustainable development

Sweden has undertaken the United Nations 15 -year goal on sustainable development and this has been met by a lot of initiatives and curiosity from stakeholders in order to together meet the goals by 2030. However, to assess the Swedish manufacturing industries awareness of sustainable development the concept is brought to a more holistic level in this report not to dig too deep into the details of each goal. Hedenus et al. [6] divide sustainable development into three categories, the ecological, economic and social dimension of sustainable development. In short, the ecological dimension refers to the capacity the environment has to offer us, such as for example, clean water, fisheries, croplands etc., but also the capacity of the environment to assimilate emissions and other forms of impact on nature we should protect.

The economic dimension refers to finite resources, simply, fossil fuels, metals and other substances found in the crust of the earth, usually without further thought extracted by the human. But these are not renewable. The economic dimension includes also monetary capital, i.e. assets humans have constructed and this includes roads, buildings, factories, i.e. different important infrastructures we have today. Managing and taking care of these the right way is definitely contributing to sustainable development. The social dimension refers to the enhancement of human well-being by building social institutions and robust structures.

Sustainable development is something most companies want to highlight they are working with. The level of awareness regarding the definition and everything included in the concept is unclear, though. When asked about the companies work towards a sustainable future they end up talking about the good they are doing for the ecological dimension. A lot of effort is put into waste recycling and reduction. The choice of electricity sources is well debated and bought from renewable sources to the extent possible. The quality of the manufacturing is on spot, and if not, robust systems to recycle and reuse unsuccessful assets are built and managed, for example, metal parts being re-melted. The amount of scrap is nearly negligible and if not some companies business idea is actually built solely on receiving scrap from customers and producing raw materials from it. Waste handling, and in this case meaning plastics and smaller waste that arises not directly from production itself but around it, could seem questionable sometimes though, but mostly the answer was that the amount waste is not significant.

Negligible emissions are often a goal and effort is put to reduce these, as a concrete example a company has reduced their volatile organic compound emission to largely be inferior to the authority control limits, by the aid of coal filters and this is something they are proud of. Smart systems are made with regards to energy use, internal processes that create waste energy in form of heat is basically always reused for factory heating purposes but also, to use for heating purposes of private people.

However, the system limit is usually drawn right around the companies' walls. As an example, one company states that the environment is very important for the company since the customers are dependent on the nature to grow their crops. However, as they are at the same time considered to be the second biggest consumer of metal tubes in Sweden and uncertainties regarding the sustainability policies of their suppliers prevail. Other examples include not having too much information about suppliers of iron ore and thus, the ethics regarding the mining processes is a topic the companies are unaware of.

More than companies realize they are making contributions to the economic dimension of sustainable development. An ambition is to make quality products that last. A 20-year lifetime, with a possibility to get an upgrade of your product at the end of the lifetime, instead of spending money on a new product, is rather a rule than an exception. Thinking in this way also definitely reduces waste. In addition, companies have adopted a sustainable way of thinking especially when it comes to metals. The importance of respecting finite resources is emphasized, such as rare metals for example, and robust recycling systems are in place. The image is also of great importance for companies and in most of the cases the images are embedding messages regarding sustainability, i.e. companies want to be recognized as the one providing you with the most energy efficient solution of the market.

From an employee perspective, health and safety and other benefits are offered by the employer to promote social benefits of the employer. Private insurances are offered and healthcare through the work. The advantage of having a gender-neutral parental leave is something that Sweden is famous for. This reflects some extent the gender equality improving in the country. Training of employees is highly valued as well, at some companies the newly employed are sent to a school for some months to master the required skills for the work, such as for example for welding. Companies even had high-schools where they train the students to become a highly skilled worker for that industry.

6.4.2.2 Japan's approach towards sustainable development

Prior to the United Nations 15-year goal on sustainable development, the 2030 Agenda, Japan had already started to implement a sustainable society through environmental, economic and social developments. Japan's approach towards achieving the Sustainable

Development Goal (SDG) formed by UN is by focusing on the eight primary guiding principles [7]:

- Empowerment of All People.
- Achievement of Good Health and Longevity.
- Creating Growth Markets, Revitalization of Rural Areas, and Promoting Science Technology and Innovation.
- Sustainable and Resilient Land Use, Promoting Quality Infrastructure.
- Energy Conservation, Renewable Energy, Climate Change Countermeasures, and Sound Material-Cycle Society.
- Conservation of Environment, including Biodiversity, Forests and the Oceans.
- Achieving Peaceful, Safe and Secure Societies.
- Strengthening the Means and Frameworks for the Implementation of the SDGs.

The visited Japanese companies were evaluated with these eight important principles in focus. A total of eleven manufacturing industries from automotive to machining industries were visited to document the key issues and progress with respect to sustainability. An attempt is made to cover most of these principle areas, however, a more profound research and time are required to clearly address all the areas of sustainable development. Nevertheless, a deep insight into a few key areas of sustainable development is mentioned in this section of the report.

Almost all the companies followed continuous improvement for the environment. Kaizen, defined as the practice of continuous improvement [8], was implemented in the industries which follow a long-term approach, where small incremental changes in the process are made to improve the overall efficiency and quality of work. Transportation solutions with minimal environmental impact, reduction of product fuel consumption, emissions, and noise; reducing the usage of harmful raw materials, minimization of generated waste, public awareness, increased awareness of employees on environment and finally, promote research and development to provide potential solutions to have an eco-friendly production were the main criteria in the manufacturing industries. However, the industries work with these criteria's to a different extent. The industries claim that they do timely evaluations and make necessary changes to meet their targets in these areas, but there are a lot more challenges and improvements required to reach the ultimate goal.

Energy conservation is one of the major challenges that companies identified. Most of the industries today have been consuming a lot of non-renewable energy for almost every purpose. Several of the companies have taken a big initiative in installing solar panels in offices and factories and they claim that these panels can cover the entire electricity usage of the office spaces or about half of the electricity usage in an assembly shop. It is inevitable for a few industries to consume non-renewable resources and in those cases, the companies have tried to cut down on automation. Jidoka is automation with human intervention, thus this does not only cut down the costs and power consumption but also assists humans in doing any tedious tasks. An example of an intervention cutting power consumption were energy-efficient welding robots that consume electricity while accelerating but while breaking the motor of the robot becomes a generator and suddenly it starts to generate electricity. Fuel cells for forklifts was not a rare sight either. Other electricity sparing activities included having dedicated pauses during the day while the lights of the whole plant were switched off. Using LEDs for lighting has provided a step closer to SDG as well. The Japanese industries are working with keeping the electricity consumption low and the main driver for this is not only the sustainability aspect but also, the electricity in Japan is very expensive and thus, as a consequence the companies adopt several electricity sparing strategies or generate their own. For example, a company producing machining tools used their wood waste to generate their own electricity.

Other interesting observations regarding energy conservation and green energy include one company that had moved a whole factory underground. The original purpose for this was the requirement for a clean room and no available space was obtained to build this, and even though, that specific environment is not needed anymore, the factory is still situated underground and the whole thermal energy consumption of this factory is covered by geothermal energy. On the contrary, some observations regarding wasting energy were made, though. Vast amounts of excess heat were produced at heat treatment processes and this energy was simply left to waste. No processes of extracting the heat and using for other purposes were installed, and here clear improvement regarding this could be spotted. Overall, a "green ratio" of about 30% of the company property has been reached, which signifies the percentage of the property that is working on clean energy. However, the progress in this area is quite slow as there are many hurdles to overcome.

Recycling seems to be one of the key actions for a sustainable society. They claim that without recycling the resources will run out in the country, as the country is quite small. Recycling was established everywhere. Failed products are disassembled and sorted carefully and scrap is collected and send back to vendors for them to produce new raw materials. An interesting personal anecdote was provided by an American citizen who was our guide for a visit. It seemed appropriate to ask his opinion on the recycling since he had a reference point in the United States. He told us that recycling is regulated by law and is practised by the industry as well as private people. Once, he had done his best sorting his private waste, but apparently, it was not done good enough, and thus, the next day all his waste was piled up in front of his door for him to sort it out again. This anecdote captures the mentality in Japan regarding recycling and environmental awareness. In addition, the customer needs to pay to recycle their waste, and since by the law, they are forced to do this, they have no choice.

Japanese industries are committed to building a sustainable society. The ageing of the Japanese population is a result of one of the world's lowest fertility rates combined with the highest life expectancy. The ageing and decline of the working-age population have triggered concerns about the future of the nation's workforce, the potential for economic growth, and the solvency of the national pension and healthcare services [9]. Hence Japanese industries provide high importance in encouraging the development of the younger population who hold the key to next-generation technology. "Hitozukuri" is one such program employed by one of the industries to develop the youth and provide support for the disabled. Some industries send the technical experts to provide lecturers to high schools to nurture the children's creativity. Factory tours for primary school students, local residents and providing hands-on activities to promote science, technology and engineering. Encouragement of activities to promote environmental awareness in the local communities. From the employee perspective, the management has taken a big step towards occupational health and safety. Companies encourage community support programs and projects with a focus on safety and security. Along with other health and safety regimes, some industries have taken up an innovative step in allowing its employees to express their health conditions by using “emojis”. In addition, to nurture the skills of the workers, they are provided with an opportunity to compete in the world level skill competitions. Also, the management provides its employees with an opportunity to improve their standard of living by providing two-year correspondence programs.

The visited manufacturing industries understand the sustainable development goals clearly and making a continuous effort towards achieving the targets. In conclusion, with respect to the SDG, it can be witnessed that Japan has made a considerable progress in the social development. In terms of empowerment of workforce, achievement of good health of all its employees, promoting technology and creating environmental awareness, Japanese industries have made a very good progress. However, the progress with respect to environmental development has been slow. It must be understood that achieving a sustainable environment is a lot more difficult than other aspects of SDG. It can always be debated if the industries have really employed things that they mention, it is something that only time will tell.

6.4.3 Comparison Japan vs Sweden

The preceding sections described the perceived status regarding sustainability in industries in Sweden as well as Japan. Here follows a comparison between these countries.

Perhaps the most outstanding difference and somewhat a surprising finding is the portrayal of the companies’ attitudes towards sustainability. In Sweden, sustainability is the hot topic, and the goals of the companies are always established around this and a clear articulation of the companies work towards a sustainable society is obtained. In Japan, the articulation regarding this matter is not too clear. Sustainable development could be stressed as one of the major goals of a company and it could completely be missing. At Japanese companies, the emphasis was rather put on efficiency, quality and continuous improvements of production, and naturally, sustainability is embedded in these objectives but the presentation of the perspective is clearly different. This does not mean that Japan does not put effort into sustainability as much as Sweden, they do. The difference is that while Sweden is putting effort into implementing robust systems to work towards a sustainable society Japan already have mostly these in place.

The Japanese law of recycling seems to be deeply rooted in the culture and lifestyle and can be substantially noticed. Products not meeting the quality requirements were carefully disassembled and sorted according to the respective properties and the materials were sent back to vendors to be turned into raw materials again. Similar types of activities were practised in Sweden for the waste generated in production. An interesting difference is, though, that in Sweden the company sells their useful waste to raw material producers but, in Japan, the company pays to get rid of their useful raw material, and they have an obligation to do so, due to the law of recycling.

The reality that the electricity is very expensive in Japan, more than double the price in Sweden, has forced Japan to implement efficient systems to reduce the electricity usage. For example, almost every company have solar panels installed on their roofs, some companies have other means of generating power, such as burning wood waste or developing smart robots to generate power in operation, as well as keeping dedicated pauses during the day to switch off the lights in order to reduce electricity consumption. Sweden has put effort into the implementation of smart systems to handle excess heat forming from different kinds of heat requiring operations. This excess heat is recovered and used for heating purposes, not for the plants in question solely, but, in district heating networks as means to provide heat to residential housings. The impression gained from Japan regarding this matter was not the same as the excess heat was not handled at all in companies visited (more companies should have been visited though, to be able to draw a general conclusion). However, a reason for this might be that district heating does not seem to be as popular in Japan as it is in Sweden, and is only established in metropolitan areas [10], and thus, the infrastructure for this kind of heating might not be widespread enough to be used as an energy efficient solution.

Regarding a sustainable society, efforts to raise the society's interest in industry and manufacturing was significantly a more important task in Japan. Nearly all companies had established programs for school children to become interested in industry and manufacturing and they were invited to visit and perform fun activities to gain an understanding about the technologies and operations in the factory as well as environmental awareness. These children could be everything from preschoolers to high-schoolers. The basic idea was to attract their interest at an early stage before they have chosen a career path, because naturally, then it would be too late. In Sweden, programs similar to these are rare. Usually, initiatives for plant visits comes from the school side rather than the industry. Instead, the effort is put into students who have already chosen a convenient orientation for example for high school studies or university studies etc. However, as described in the section above, these initiatives in Japan are rooted in the problem with an ageing society that they are trying to concur. The situation with an ageing society is not as extensive as a problem in Sweden and thus these measures might not be needed.

Both countries are putting significant effort into their employees regarding benefits such as health care and insurances as well as their job skills. Regarding job skills the emphasis in Sweden is usually put on an early stage training, i.e. it is not uncommon that companies own or closely collaborate with high schools for children to enrol and thus, early train skills for these specific industries, and the idea is that they later become an employee at the company. As newly employed they are offered programs to polish their skills in various shop floor tasks, such as welding for example. In Japan, the impression was that training is continuously received throughout their career and that these skills they learn are highly credited and visible as the employees receive a ribbon to wear to express the skills they possess. Newly learnt skills do not seem to be valued as prestigiously in Sweden.

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6.5 Research in Manufacturing

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This section focuses on the influence of research and development in different industries in both Sweden and Japan. According to Statistics Sweden, R&D expenditures in Sweden has increased by 7 billion SEK since 2013, for a total of 137 billion SEK in 2015, while the R&D share of the GDP has stayed above 3 per cent since 2007 (SCB, 2016).

In July 2017, an intergovernmental economic organization called OECD "*Organization for Economic Co-operation and Development"* based on France, reported their member countries *Research and Development Statistics (RDS)*, Japan and Sweden shares in the same level in percentage of GDP when it comes to R&D investments, as presented in Table 1.

TABLE 1. COMPARISON OF SWEDEN AND JAPAN R&D GDP AND RESEARCHERS PER THOUSANDS EMPLOYED (OECD, 2017)

Country	Expenditures on R&D as a (%) of GDP	Researchers per thousand employment
Sweden	3,3	13,6
Japan	3,3	10

The projects universities apply for in Sweden often have collaboration with industries as one primary criterion. In particular, supporting small and medium-sized enterprises with partial financing to transform collaboration ideas into profitable new products, services and processes.

The contribution of R&D has played a significant role in the area of innovation, technology, company's economic status, revenue and environmental impact. Most of the companies have their own R&D team to work closely with end users, buyers and researchers at universities.

We have studied the different companies in Sweden and Japan and their policies towards R&D and collaboration with universities. Have also reported the improvements after investing time and money in R&D sector. This section of the report presents the findings based on three questions:

1. How do manufacturing companies perform research?
2. How do current research efforts help solve critical issues in the factory?
3. What critical long-term issues affecting the competitiveness of the factory would benefit from research involvement?

6.5.1 The Swedish perspective on manufacturing research

6.5.1.1 How do manufacturing companies perform research?

State of research practice in Swedish manufacturing

A number of coincidences were apparent from visits held at Swedish companies. In all cases companies considered themselves as best in class representatives of their market, and that a fundamental condition to attain this level of competence was a continuous acquisition of knowledge through research. Without exception, visited companies had clearly assessed their core competencies, identified a vision of the future, and reasoned how research would contribute to achieving this vision. The practice of research at all sites was interpreted as a culture of continuously acquiring increased skills focused on the development of new technologies that facilitated the design of new products. Indeed, research was defined through structured processes with clearly defined milestones. In all cases, the practice of research was also characterized by its customer focus. This was exemplified by the constant testing of products in development in customer conditions, teaching customers how to design new products with newly developed production processes, and allowing customers to prototype products in-house.

In line with previous empirical findings, focus on the development of new technologies or processes that improved production, without the prerequisite of a newly developed product, was not present at all sites. Similarly, differences existed in the comprehensiveness of research that is whether functions other than R&D were involved in research. This occurred only two of the visited companies. At these companies, research did not only include R&D specialists but also cross-functional teams from production and product design.

Significantly, two of the companies studied companies viewed research as indistinguishable from their core competence. This included a manufacturing company in the process industry and a manufacturer of very high-efficiency inductors. Indeed, in the words of the manager of one of these companies "*low hanging fruits pay for our research, while high hanging fruits drive our research.*" Important to note was the fact that knowledge level about core competence did not correspond to firm size or revenue. In fact, it was the smallest visited firm who was often asked to function as a research site for manufacturing companies with a global footprint. An outlier of note in this sample was the fact that only one of the visited companies identified research with innovation and, to this end, actively measured research output in the form of patents.

The research facility – An internal and external playground

Facilities, where research is developed in Swedish manufacturing, presents a homogeneous outlook. All visited sites had R&D facilities at the same site as their production facilities. This provided customers with the possibility to prototype and test equipment. Research facilities provided companies with not only the possibility of investigating future trends but also mimicking the processes of existing and potential customers. Again, the connection to customers by way of research was readily apparent, as expressed by a factory manager "*We allow our future clients to make test runs and prototypes with us. This helps our future clients by not disrupting their production*."

Collaboration – Research as a multidirectional benefit

Consensus existed in what was understood as research collaboration. Invariably, the practice of research in Swedish manufacturing is experienced as a continuous collaboration including customers, universities, and research institutes. This level of collaboration was interpreted as a multidirectional benefit. Where companies learn about customer needs, customers get access to prototype and testing facilities, while universities work in joint development projects with manufacturing companies. As expressed by the director of research at one of the visited sites "*Our company benefits from research with improved products and processes, the university benefits from our company through the participation in new projects*."

6.5.1.2 How do current research efforts help solve critical issues in the factory?

Product diversity - A research challenge

In agreement with prior research findings, Swedish manufacturing facilities were challenged by satisfying customer needs through increased product diversity and product customization. According to one of the informants, "*our current production includes 25 – 30% special orders, a trend which we expect to increase.*" Increased product diversity was identified by companies as a driver of change for production processes and a key area for research efforts. However, the degree to which research focused on this concern is currently spent or will be devoted varied widely.

A tale of two foci – Solving issues at the factory floor

Salient areas for research targeting growing product diversity included: modularization of products and processes, human-robot collaboration, acquisition of technology, technology implementation, flexibility, and vertical integration. Two principles by which Swedish manufacturing companies approach these areas were illustrated during our visits in what we term an internal and external focus. The internal focus principle is based on awareness by Swedish manufacturing companies about the capabilities and limitations of their production processes and a need to perform factory improvements. Research is perceived as an engine that drives factory improvements and that "*research can help solve the difficulties faced by production*," as expressed during our visit to a facility of the process industry. The external focus principle was best expressed by a production manager, "*the challenge is not to bring in new technology but to pass it to production*." On the one hand, this principle assumes that opening up to the world outside the factory is critical to keep research efforts at the forefront of knowledge. On the other hand, the external focus principle signals that procuring external technologies is not sufficient for improved factories, but that when technology is acquired from the outside world the true aim of the research is developing a fit to the needs of the factory.

6.5.1.3 What critical long-term issues affecting the competitiveness of the factory would benefit from research involvement?

Focus on technology

Several of the Swedish manufacturing companies visited agree that new technology will have a large impact on long-term competitiveness. The expectations are that most of that will be in the area of product development, incorporating new technology in the products to take them to new heights. However, it is understood that new high-tech products will require new production processes even though much of the focus is placed elsewhere. One of the visited companies mentioned developing processes to support new markets as a long-term issue that needs research involvement, as the knowledge of these new markets and how to adapt to them is a difficult question. Another issue that also was brought up was how the development of new technology can make old materials, and related production processes, obsolete. This forces the development of new processes to deal with the new materials, which requires the heavy involvement of research to be successful and competitive in the long-term.

6.5.2 The Japanese perspective on manufacturing research

6.5.2.1 How do Japanese companies perform research?

State of practice in Japanese manufacturing

The diversity of companies visited in Japan offered a broad range of industries and their approach to research at manufacturing companies. All sampled companies considered themselves market leaders. Without exception, Japanese companies related their core competencies to the development of technology. Indeed, technology development was not a recently acquired interest but a decade-long effort at all levels of the organization, from CEOs holding PhD degrees who actively participate in the research community to assembly operators who contribute to the sharing of knowledge at manufacturing companies even after retirement. On-site discussions revealed that Japanese companies performed research through specialists working in a silo with limited interaction with other silos.

Three themes were associated with the need to perform research in Japanese manufacturing: an ageing population, specialization as a countermeasure to Chinese manufacturing, and the limited resources of Japan. We interpret these findings as pressing issues that jeopardize the leading position of Japanese manufacturing and research as possible an enabler to sustain a competitive advantage. The following excerpt from a discussion with a human resources manager exemplifies the above, "*We cannot wait… we need to make these changes happen fast. We need to restructure our organizations to address current challenges. A solution to this is the acquisition of new knowledge. It is crucial for us to acquire new talent, competencies, and technologies outside of traditional manufacturing*."

Our empirical data shows that Japanese companies actively work with research in the development of technology. During our visit, 13 of the 14 manufacturing companies and universities mentioned the terms smart factories, Internet of Things (IoT), human-robot collaboration, and advanced manufacturing. Additionally, six out of these 14 companies demonstrated products, technology roadmaps, and organizational processes involving research related to these keywords. A note of interest is that the term innovation, which is closely related to that of research at manufacturing companies, was mentioned only once during our visit. We do not interpret this as an error in our data collection, but that a different construct of research and its relation to new discoveries successfully introduced into a market, is at play. Figure 5 shows an example of progress in data visualization in Japan.

FIGURE 5 JAPANESE MANUFACTURING COMPANIES AND THEIR EXTENDED EFFORT TOWARDS THE DEVELOPMENT OF SMART FACTORIES

The research facility – Experimenting at close quarters

The Japanese research facilities present diversity of approaches were half of the manufacturing companies reported that their research facility was in the same building as production. Data are insufficient to draw conclusions on this choice of strategy, yet all manufacturing companies reported close collaboration with supplier or partner companies as part of their research initiatives inside their facilities. We term this approach to research experimenting at close quarters. Opposite to this, only one manufacturing company described as having a research facility were customer were allowed to prototype with their newly developed products.

Collaboration – Research as an inner circle dialogue

Data show that Japanese manufacturing companies coincided in their approach to research collaboration. We describe this approach as research as an inner circle dialogue. Japanese companies preferred to collaborate in the development of research with suppliers or clients after a long period of commercial interaction took place. Collaboration with universities was limited to basic research in a specific field such as material sciences, yet Japanese companies reported recent efforts to cooperate with universities and research institutes in a variety of fields including energy, sustainability, advanced manufacturing, and digitalization.

6.5.2.2 How do current research efforts help solve critical issues in the factory?

An internal focus

As described previously, research in Japan was very much like an inner dialogue. Companies generally performed research on their own, without the involvement of research institutes and universities. As a direct implication of this, much of the focus was on the issues that the companies identified as critical in the short term for them, often related to the products. Research performed seemed successful in this area, as the companies we visited and talked to all were successful and profitable and had been around for a long time.

6.5.2.3 What critical long-term issues affecting the competitiveness of the factory would benefit from research involvement?

The next era in manufacturing

Most of the research focus in Japan was on the product level and in the capabilities of machines and other components of a production system. Little focus was seen on the system as a whole, how to utilize the data gathered by new connected milling machines for example. Production, as seen from a system perspective, could greatly benefit from more research involvement and collaboration between companies and universities.

6.5.3 Summary and comparison

In many ways, research in manufacturing in both Sweden and Japan was very similar. It’s considered a core competence that focuses on the customer. However, Swedish manufacturing has a larger focus on collaboration with universities and between the research and production departments of the company and is often performed with a cross-disciplinary team as opposed to a specialist. Table 4 presents a summary of both Swedish and Japanese research in manufacturing side-by-side.

TABLE 2. PRESENTS THE KEY TAKE AWAY BETWEEN THE DIFFERENCES BETWEEN SWEDISH AND JAPANESE APPROACHES TO PERFORMING RESEARCH

	Swedish manufacturing	**Japanese manufacturing**
State of practice	Customer focused research	Customer focused research
	Research performed by cross-disciplinary teams	Research performed by specialists in silos
	Research is a core competence	Research is a core competence
Facilities	Research and production in the same building	Research separate from production
	Interaction with customers frequent in research facilities	Limited interaction with customers in research facilities
Collaboratio n	Actively collaborating with universities	Collaboration with universities very limited but said to be growing
	Dynamic interaction with customers	Highly dynamic interaction with suppliers and partner companies

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7 Conclusions

This chapter lifts out the main findings from each focus area studied in this course. The course has granted a unique insight into Japanese and Swedish manufacturing, and the many similarities and differences that exist between them.

7.1 Quality Assurance within Integrated Product and Production Development

Figure 2 (refer section 6.1.3.3) presents the summarized comparison between Japanese and Swedish suppliers' perspective on the importance of key areas in quality assurance with integrated product and production development. Flexibility in manufacturing systems, Problem tracking, Functional testing and Quality audits all shared a similar level of importance in both Sweden and Japan. The other areas were considered more important by the Japanese companies.

7.2 Digitalization and Industry 4.0

The identified similarities and differences between Swedish and Japanese manufacturing companies with regards to digitalization and Industry 4.0 are summarized below.

7.2.1 Similarities

- It is difficult to attract a younger workforce to the manufacturing industry.
- IT departments are conservative, not pursuing the Industry 4.0 agenda.
- With regards to Industry 4.0 maturity, companies in both countries aim for stages 5-6 but are currently at stages 3-4.
- Companies recognize the importance of having higher information and control levels.
- Kanban systems are used for data visualization.

7.2.2 Differences

- Japanese companies use predictive maintenance for customers' equipment.
- Swedish companies collaborate to a much larger extent with research and academia.
- Level of data visualization in Japan was higher at some companies compared to Sweden.
- Japanese companies track performance on an individual level, which is rarer for Swedish companies.

7.3 Production processes

- Both countries are specialized in high tech production.
- Swedish industry is more influenced by Japanese production philosophy than the other way around.
- From the visited companies in both countries, it was shown that the Japanese industry uses visual inspection more than Swedish industry.
- Lack of skill in international languages can make it difficult to communicate with Japanese enterprises, which can lead to missed opportunities for collaboration.
- Both countries put great emphasis on recycling of used household products but have slightly different ways of making sure old products is recycled in a proper way.

7.4 KPIs and sustainability

The concluding findings are summarized below for KPIs and sustainability respectively.

7.4.1 KPIs

- In the Sweden, the extensive focus was placed on quality, electricity consumption, and accidents.
- In the Japanese factories usually there is a focus on target objectives for the day and in workers' expertise and education.
- Swedish companies presented KPI information on digital screens, while Japanese companies used pen and paper systems.
- Japanese companies relied more on continuous quality control, while Swedish companies focused more on finished product quality control.

7.4.2 Sustainability

7.4.2.1 Japan

- Efforts to raise the society's interest in industry and manufacturing was significantly more important in Japan.
- There were programs for development of youth and support for disabled, and programs for school children in manufacturing industries.
- Factory tours for students and local residents were common.
- Hands-on activities to promote commercial and environmental awareness were often seen.

7.4.2.2 Sweden

- Programs similar to those presented in the previous paragraph were rare in Sweden.

- Initiatives for industrial visits are planned from the academic side rather than the industry itself. Instead, the effort is put into students who have already chosen a convenient orientation for example for high school studies or university studies.

7.5 Research in manufacturing

The main findings from the focus area research in manufacturing are as follows:

- Both countries have very customer focused research, and research is considered a core competence.
- Research in Sweden is mainly performed by cross-disciplinary teams, while in Japan it's performed by specialists in silos.
- Production and research are separated in Japan, while in Sweden they co-exist in the same building.
- A larger amount of customer interaction in research facilities was experienced in Sweden, while more dynamic interaction with suppliers and partner companies was identified in Japan.
- Collaboration with universities was more active and common in Sweden.

8 Participating parties and contact persons

8.1 Visited companies and universities in Sweden and Japan

In total, 20 visits were made during the course, each with a different execution depending on what the receiving party could offer. Some visits were just a tour with a guide, while other included presentations, factory tours, and discussions in smaller groups. Out of these 20 visits, 17 were companies which are presented in Table 1 and 2 where a brief description of each company is given. In addition to the visited companies, three universities were visited in a workshop setting to learn about respective research focuses. The visited universities were Keio University, University of Nagoya, and Tokyo University.

TABLE 3. COMPANIES VISITED IN SWEDEN

Company	Description	Company logo
SwePart Transmission AB	220 employees. Produces gearboxes and components for it.	
Xylem Water Solutions Manufacturing AB	830 Employees. Produces all technology needed for turning waste water into drinking water. At the visited factory they produce Flygt pumps.	
Väderstad AB	650 employees. Produces farming machines for cultivation, seedbed preparation and seed placement.	
Nordic Brass Gusum AB	130 employees. Produces different brass alloys. Produces three main types of products: Ingots, rods and nuts.	
Höganäs AB	1800 employees. Produces steel and metal powder.	
Magcomp AB	12 Employees. Produce inductors and induction heating systems by using soft magnet materials. A spin-off from Lund University.	

TABLE 4. COMPANIES VISITED IN JAPAN

Company	Description	Company logo
UD Trucks Corporation	6210 employees. Produces medium and heavy-duty trucks.	
Makino Milling Machine Co., Ltd.	4600 employees. Produces milling and electro spark machining, EDM, machines.	
Toyota Motor Corporation	364 450 employees globally. Produces cars.	
Denso Corporation	168 810 employees, 39 000 out of which are based in Japan. Produces wheel-speed sensors and air-bag sensors.	
Yamazaki Mazak Manufacturing Corporation	8000 employees, 4000 outside Japan. Produces different types of machining centers, e.g. milling and laser processing machines.	
DMG Mori	12 000 employees in the entire company. Produces machine tools, machining centers, and turning centers.	
Asahi Beer	30 000 employees globally. Produces beer, other spirits, and wine.	
Mitsuboshi Diamond Industrial	324 employees in Japan. Produces tools for hard and brittle materials such as glass and sapphire.	
Panasonic	Part of Panasonic, which employs almost 275 000 globally. Recycles used home appliances, such as TVs and refrigerators.	
Kyoto Tools	306 employees globally, 195 in Japan. Produces hand tools and measurement instruments	
Mitsubishi Cars	3040 employees. Produces cars.	

8.2 Participating Universities from Sweden

23 Ph.D students from the following 7 universities in Sweden participated in the formation of this report on International Production 2017/18.