# INTERNATIONAL PRODUCTION

A comparison of the manufacturing industry in Sweden and India

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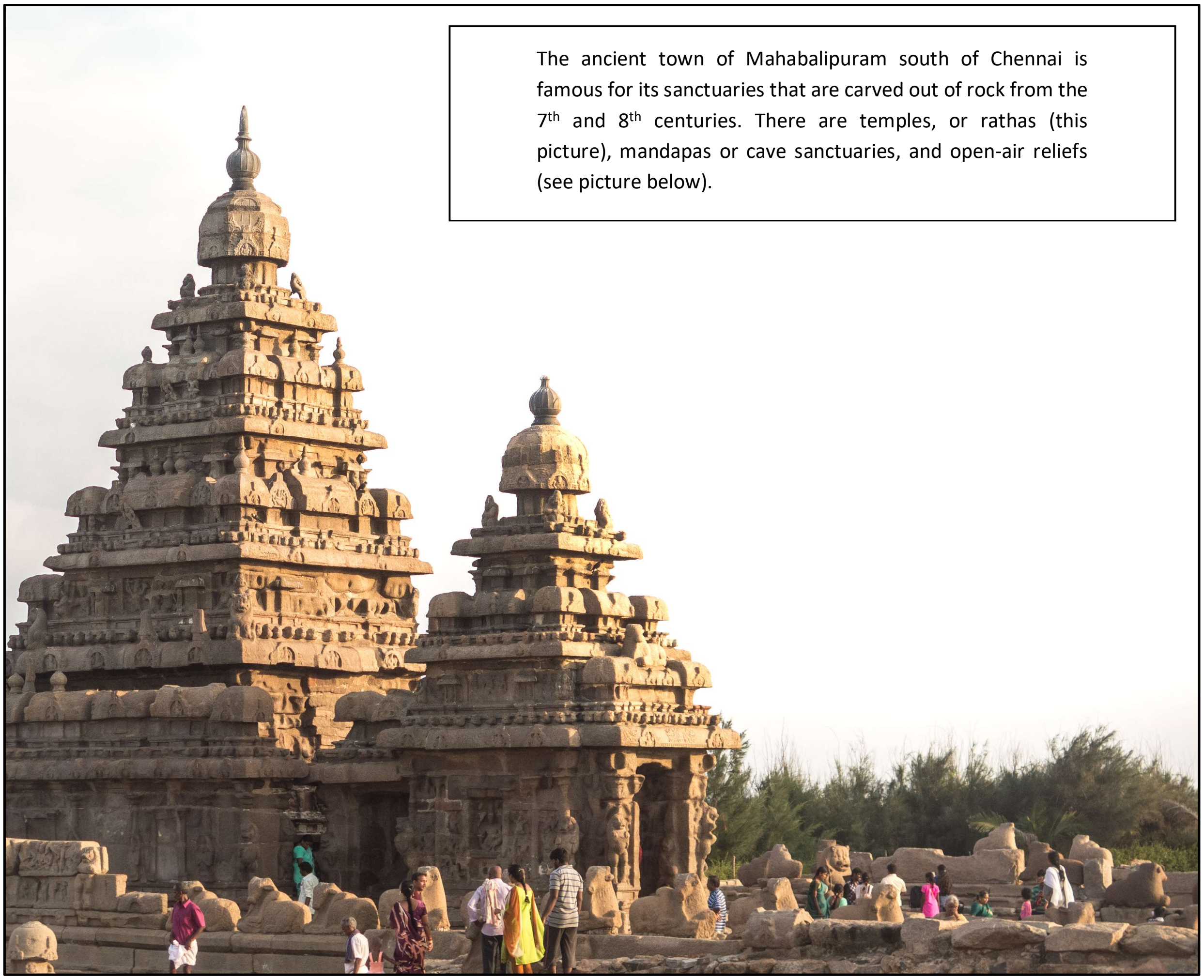

The ancient town of Mahabalipuram south of Chennai is famous for its sanctuaries that are carved out of rock from the 7th and 8th centuries. There are temples, or rathas (this picture), mandapas or cave sanctuaries, and open-air reliefs (see picture below).

## IN SHORT

In an industrial world that spans across ever-increasing geographical, cultural and technological distances, an understanding of **globalization in manufacturing** is essential. In the PhD course "International Production", PhD students from various Swedish universities have visited production facilities in **Sweden** and **India** to gain insights on similarities and differences in manufacturing between the two countries. Experiences are in this report shared across **five focus areas**:

- **Integrated Product and Production Development**
- **Digitalisation**
- **Production Processes**
- **KPIs in Production**
- **Inter-organisational collaboration**

The Swedish and Indian manufacturing industry face different conditions in the **business market, labour market, environmental status** and **cultural constraints**. These conditions suggest that the course of action for the future of manufacturing might differ between the two countries: **Sweden towards advanced mass customization** and **India towards cost-effective mass production**.

At the same time, the two countries share common ground that opens up for extended collaboration, including e.g. **awareness**, **knowledge** and **technology** for **sustainable production**, **globally unified product development** and **production processes**, and **visions**, **strategies** and **policies** for **competiveness** of manufacturing firms on the **global market**.

It is clear that a **continued** and **deepened collaboration** between Sweden and India is necessary for the well-being of globalized manufacturing, and it may be of great **economic**, **social** and **environmental** value for both countries. We propose that this collaboration spans across **operational**, **tactical**, **strategic** and **governmental levels**.

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Right: Typical meal in the south of India.

Below: Poverty is ever present, like among these temporary living arrangements in Bengaluru.


Above: The cow is holy and many are roaming free around the cities.

Left: It is good to have locals to guide you around, here Mahesh and Varun is leading the PhD Student train.

# INTRODUCTION

There are a number of megatrends that will shape the future of society, such as demographic change, climate change, digitalization and globalization. These trends have a significant impact on one of the backbones of society: the manufacturing industry. The changes brought by these trends are expected to transform the way manufacturing companies do business, and as a response, strategic initiatives have spurred across the globe. In western countries, strategies for a new type of industrialization include “Industrie 4.0” in Germany, “Smart Industry” in Sweden, and the “Industrial Internet Consortium” in the US. However, these strategies exist across the globe, e.g. “Made in China 2025” that aims to make China a major manufacturing player by 2049, and “Make in India” (see Figure 1) that aims to foster innovation, promote multi-national investments and build world-class infrastructure to boost the domestic manufacturing industry. These strategies have made production a hot topic to say the least!

This report shed some light on these megatrends by providing valuable insights from twenty PhD students and one professor from seven Swedish universities. The insights are formed as a result of the course “International Production”, a bi-annual PhD course within the graduate school Production 2030. The course has the overall goal to increase the awareness and understanding of one of the currently strongest trends in manufacturing – globalization. In addition, it supports the build-up of highly competitive knowledge and experience around analysis and execution of complex global production systems. Globalization is a crucial aspect for the manufacturing industry today; the historically so important borders defended by customs and armies between countries and unions are more and more erased by international industry operating on a global market and with ownership distributed across the globe.

The course International Production is funded by Vinnova through the Swedish strategic innovation initiative Production 2030, and supported by the Swedish Production Academy that consists of leaders and PhD students of the production research and education at Swedish universities. The course aims to increase skill of the coming PhDs in the area of production and product development to work successfully for their companies and universities on a global arena. Previous versions of the course have included visits to China, Italy, Brazil and east Europe. In November 2016, the latest edition of the course completed the final part of four with a visit to India, one of the most interesting economies and countries in the world at the moment. India represents not only a huge market for industrial products but also a potentially strong industrial competitor and partner.

Questions around differences and similarities between production systems established in different countries with different cultures and largely differentiated GDP per capita are of highest interest to answer in order to achieve successful implementation of globalization within the manufacturing industry. This report is the final stage of a more than a year effort with visits to national production facilities in Sweden, lectures and extensive planning for the trip to India, visits to Indian production facilities and universities, and the dissemination of the report. The aim is to highlight challenges for International Production and thereby contribute to a continuation of the successful industrial co-operation between Sweden and India.

Figure 1: Logotype for India’s national programme “Make in India”.

## Culture

Sweden's population is close to 10 million people, with a skewed distribution towards elderly people (median 41,2 years). The trend towards a greater share of older population will continue to grow over the next decades, which naturally affects the labour market. In fact, Sweden has the highest number of labour market population aged 50-64 in Europe. Consequently, the Swedish manufacturing industry must support suitable jobs for an increasingly larger number of older workers. Still, Sweden as a nation with a smaller population than some of the visited Indian cities, has an un-proportionally large number of historically strong company brands compared to its population. At the same time, the Swedish economy heavily rely on the competitiveness of those brands and emerging new ones. In contrast, India has a population of close to 1,3 billion people, with a skewed distribution towards young people (median 27,6 years). This means that over the next coming decades, India will have a booming labour market and a sustained availability of quality workforce. The young population also holds a strong innovation potential, meaning that the Indian manufacturing industry can utilize a growing labour market to drive economic growth.

India has a fabulously interesting cultural history emerging from the high cultures developed along the river of Indus and firstly described already in 3000BC. In recent times from 700AC, and until the liberation from the British Empire in 1947, the Indian history has been heavily influenced by external powers. Today, the Indian economy is the third largest after China and Japan, and GDP grows with an annual rate of 7-8% (compared to 3-4% in Sweden). The growing domestic Indian market and the recent Indian policy of *Make in India* create an interesting mixture of market potential, the need to master establishing of manufacturing in India and at the same time to urgently understand the short term- as well as long-time effects of establishing manufacturing operations within an economically booming country. *Make in India*, the 2014 launched initiative is devised to transform India into a global design and manufacturing hub by motivating global companies to invest in Indian manufacturing sites and establishing in the six geographical "industrial corridors" and "industrial cities" with strong infrastructure.

Even before Make in India, there were initiatives that promoted Indian manufacturing, e.g. the Special Economic Zones (SEZ) established in 2005. SEZ intended to work as engines for economic growth by promoting e.g. export of goods and services, investment from domestic and international sources, and creating of employment opportunities. This has supported investments in Indian manufacturing, and was particularly noteworthy during the visit to Salcomp in Chennai (located in the Nokia Telecom SEZ). Still, the effects of Make in India were evident during our trip. Favourable customs and duty fares are experienced as a driver for growth in the manufacturing sector, and tax benefits can act as promoters for in-house production and development of local supply chains. These growth mechanisms are of course not only relevant for domestic companies, but also international. In the long run, international companies might be inclined to move a larger amount of their operations to India (e.g. bringing suppliers and setting up a complete domestic supply chain), as compared to sending parts or kits for final assembly to be sold on the Indian domestic market.

However, there are several problems and obstacles associated with such a rapid development towards world class manufacturing as we observed in India. A non-manufacturing example is that Bangalore have experiences an almost 50% increase in population density in the last 10 years due to economic growth and job opportunities; a growth pace much faster than the average in modern history. Europe needed more than 200 years through the Industrial revolution starting in England to come to the current state of green factories, clean air, clean water, workers' rights, unions, low injury rates at work, long and paid holidays, automation of hazardous and repetitive work, Industry 4.0, low corruption and criminality, and relatively high gender equality. Considering the extraordinary pace of development in India, one can raise the question whether India can, or should, extrapolate on western experiences. Instead, there might be an opportunity for innovative disruptive technologies that can manage both the challenges and opportunities in the growing Indian market, and potentially skip several of the evolutionary phases of western manufacturing.

On the 8th of November, the Indian president spoke in an address to the nation and said that black money "and corruption are the biggest obstacles in eradicating poverty" and announced a radical step against "black money" - unaccounted wealth and fake currency notes.  Overnight the government recalled all 500- and 1000-rupi notes to be replaced by new ones. This strong move to encounter challenges of corruption in an otherwise strongly growing economy is in many ways positive, although the ripple effects of this move have caused tremendous short-term issues for a large part of the population. Further, environmental aspects are of uttermost important to India as there is, unfortunately, no denying that the current state of affairs are rather terrible. During our trip, smog in New Delhi resulted in 5000 closed schools, demonstrations, and shops specializing in marketing designed anti-pollution masks. The city was proclaimed "the most polluted city now" by CNN. However, there are positive forces acting in favour of the environment, e.g. the news of India ratifying the Paris global climate agreement in October 2016. As the sixth-largest economy in the world measured by nominal GDP and the world's third largest greenhouse gas emitter, is it crucial that India seriously works to limit the downsides of a fast-forwarded new Indian industrial revolution. Still, Indian manufacturing industry must incorporate strong and permeating sustainability initiatives. In this regard, there are likely many sources of inspiration that can come from Sweden. To support sustainability, the combination of continued economic growth with increased availability of eco-friendly technology at Indian market price is necessary.

The newspapers have during the autumn been filled with positive news for Europe as large defence- and telecom contracts with Sweden, France and Russia are signed for many billons SEK together. This, together with the increasing production from foreign companies established within India due to Make in India and other initiatives, pass a possibility for western countries to support India in this "industrial revolution". There exist great possibilities for win-win situations, where financial upsides can be balanced with all good experiences from the more than 200 years of development in Europe and other countries. Pollution, energy waste, safety, working hours, and union work are examples of areas where Swedish companies have come a far way and has a lot knowledge and possibilities to transfer in the co-operation and establishments in India.

Finally, during the trip we met a young, growing and well educated population very aware of both positive and negative aspects of a strongly growing GDP. There are many challenges to master for India, but a win-win implementation of International Production in India has all potential to not only fast forward the Indian industrial revolution but also increase wealth and life for the Indian people by supporting the growing market of the second most populated country on the planet. Sweden already play an important and successful role in industrial co-operation with India and this course has not only educated us, the PhD students and our accompanied professor, in International Production, but also helped the next generation of Production and Product Development PhD's to manoeuvre in an international and global future production.


Market area in Chennai.

# Course summary

## Purpose of course

The purpose of the Production 2030 course “P02 International Production” is to allow the participants to:

- Identify specific focus areas that pertain production systems and the manufacturing industry and are relevant to both research and industry.
- Understand and critically discuss how production is being managed in local factories in Sweden and in factories located in a selected foreign country and make comparisons on that regard according to these specific focus areas.
- Point out the challenges for Swedish companies when producing abroad.

## Purpose of visits

Several visits were conducted at Swedish and Indian factories and universities. The university visits in India gave us knowledge in how product and production engineering research is being carried out. The factory visits allowed us to observe the state of the production system and ask questions about specific aspects in focus, such as automation, ways of working, social challenges, or integration of product and production development.


A decimated crew at Mahindra automotive in Pune.

## Sweden

Five manufacturing companies were visited in Sweden. Three out five visits took place in factories owned by the Volvo Group and the Volvo Car Group, which are two of the strongest Swedish brands that acts on a global market. A summary the visited Swedish companies is reported in Table 1. It is important to note that the reflections and results presented in this report regarding the current state of Swedish manufacturing is not solely based on these visits since all of the participants also have other experiences with Swedish industry through their own research. Furthermore, some of the industrial PhD students who participated in the course were carrying out their own research in the companies we visited, which allowed us to gain more information about the advancement of the Swedish R&D in manufacturing.

Table 1: Companies visited in Sweden.

| Company | Location | Information |
|---|---|---|
| Volvo Car Group (Volvo Cars) | Skövde | Volvo Cars is headquartered in Gothenburg, Sweden and produces a wide range of cars from sedans to SUVs. Volvo Cars is owned by Zhejiang Geely Holding (Geely Holding) of China but collaborates with the Volvo Group in terms of R&D. The Skövde plant (Volvo Cars Engine) produces multiple variant of car engines, both petrol and diesel. |
| Volvo Construction Equipment | Eskilstuna | Volvo Construction Equipment is the oldest company in the world still active in the construction equipment industry. It started in 1832 with the plant in Eskilstuna. This plant produces wheel loaders, dump trucks and strategic components for Volvo Construction Equipment. Today it is one of the largest machine processing plants in Europe. |
| Alfa Laval | Eskilstuna | Alfa Laval is one of the leading global suppliers of products and solutions for heat transfer, separation and fluid handling. Examples are heat exchangers, separators, pumps and valves. Applications of Alfa Laval's products stem from food and chemicals processing to the engineering sector and mining industry. The company has issued more than 2500 patents throughout its history. |
| Volvo Group Trucks Operations | Köping | Volvo Group Trucks Operations focused on truck manufacturing, including cab and vehicle assembly, powertrain production, logistics services, parts distribution and remanufacturing. Customers are mainly within the commercial vehicles, mining and construction, agriculture, and telecom industry. Köping plant dates back to 1856 and focusses on powertrain production. |
| LEAX Mekaniska | Köping | LEAX Group is a privately-owned business group headquartered in Köping. It provides European engineering companies, especially automotive companies, with advanced machining and assembly of components and subsystems. Examples are shafts, gears and rotationally symmetric parts. |

## India

In India, ten manufacturing companies and two universities were visited in in Chennai, Bengaluru, and Pune (see Table 2). From the colonial times when India was part of the British empire, several cities have more than one name. For example, Chennai is also called Madras and Bengaluru is called Bangalore. In this report, we refer to these cities using the traditional Indian names.

Chennai is the capital of the Indian state of Tamil Nadu. It is located at the south-east coast of India, near the Bay of Bengal, and the climate is tropical wet and dry. Chennai is the fourth most populated city in India, with around 9 million people. A lot of manufacturing industries, especially automotive industries, can be found in the area. In Chennai we visited IIT (Indian Institute of Technology) Madras, which is one of the highest ranked universities in India. It is very hard to pass the tests for Indian universities since many potential students compete for few openings. You could clearly see how the campus of IIT Madras was formerly a national park, as we got to see both monkeys and deer on the campus.

Bengaluru is the capital of the Indian state of Karnataka and is situated in the midland of south India. It is called "Indian Florida" since many people move here when they retire due to the nice climate. Bengaluru is currently one of the fastest growing cities in the world, expanding from 5.5 million to 11 million in only ten years. This area is also often referred to as "Silicon Valley of India" since it acts as an important IT centre. We also visited the Centre for Product Design & Manufacturing (CPDM) at the Indian Institute of Science (IISC). Here, both we and our Indian friends, PhD students and their professor, got an opportunity to present their own area of research in a mini conference. CPDM research focusses on a unique variety of fields ranging from creativity and sustainability in the design process to biomedical engineering realizing cheap and functional prosthetic arms. IISC's campus is characterized by an interesting mix between British-style building architecture and a florid local surrounding vegetation. A group of PhD students of CPDM focusing on sustainability discussed the challenges that India is facing in terms of air pollution and citizens' wellbeing caused by a rapid economic and demographic growth.

Pune is a city with around five million people just south-east of Mumbai, 150 km from the coast and with hot and semi-arid climate. Pune has a traditional old-economic base, and most of the industries continue to grow. Both manufacturing and automobile industries are situated in Pune, which is also known for its research institute (IIT).

## Focus topics

Based on the research interest of all the participating PhD students we decided on five different focus topics and divided ourselves into five corresponding groups. These focus groups have gathered information and reflected from their own point of view respectively. The different topics are: Integrated Product and Production Development, Digitalisation, Production Processes, Key Performance Indicators (KPIs) in Production, and Inter-organisational Collaboration. The results are presented as five different parts connected to the selected topics and each part can be read as a separate section.

Table 2: Companies visited in India.

| Company | Location | Information |
|---|---|---|
| Salcomp | Chennai | The world leader in production of mobile chargers. The dedicated mass production facility hosts a mix of highly advanced machinery and assembly lines where 80% of the operators are female. |
| ESAB | Chennai | ESAB (Elektriska SvetsningsAktieBolaget) was founded in Sweden. ESAB India has four plants, where the Chennai plant is the oldest one. The facility produces welding electrodes and hosts a mix of old and new equipment, and there are plenty of manual work. |
| Polyplastics | Chennai | Produces components for the automotive sector, mainly wheel rim covers and vacuum metalizing units. It is a relatively small shop floor with three moulding machines, a paint shop, and assembly areas. The facility has an open architecture with modern equipment. |
| Volvo Busses | Bengaluru | Bangalore hosts the only Volvo busses plant in India, which employs 1200 people, whereof 800-1000 work on the shop floor. Current demands are low and production is only working on 50% capacity, which was 420 buses during 2015. The facility also includes a competence training centre, which is important since the driving style among many Indian drivers need to be retrained to accommodate new buses with many features for safety and comfort included. |
| Volvo Trucks | Bengaluru | The plant produce trucks both for Volvo brand and Eicher brand, mainly for the mining and construction industry. The plant has a capacity of 14000 trucks per year and increasing sales volumes is the currently the biggest challenge recognized by the management. Process stability is the focus area at the shop floor. |
| GKN | Bengaluru | In Bengaluru, a lot of aerospace companies have started their business in the last ten years, one of which is the GKN Aerospace design office. They design engine parts - mainly fans, hot structures, cold structures and wing structures, all in aluminium or composites. The company design parts both for military and civil use, which is why all design and testing areas are strictly restricted. The age of the staff is 22-45 years, whereof 90% have bachelor degree education or higher. |
| Mahindra Aerospace | Bengaluru | Produces on average 80.000 components for the aerospace industry per month, ending up in airplanes like cargos and charters. Currently the plant has 400 employees and since the plant expects to take over some production from Australia, the company aims to hire another 300 during the next couple of years. It is a complex process to manufacture aeroplanes, the aero structures go through the approval process from different stakeholders such as OEMs and accreditation institutions. 50% of Mahindra Group’s employees (which in total account for 200000 people) are non-Indian and come from more than 100 countries. |
| Tata Motors | Pune | Tata motors is a large international company. The plant in Pune is of 8200 acres, and the plant trip we took went over 11 km. The plant employs 14500 people, and manufactures 2500 vehicles per day. The company has focus on the lower price segment with the popular Tata Nano as a good example. They now want to reach a broader market and they have purchased both Land Rover and Jaguar which they have managed to turn profitable in a very short time. |
| Mahindra Automotive | Pune | Mahindra Automotive produces everything from two-wheelers to trucks, and it is the leader in the utility vehicles production in India since 1947, when the first Indian UV was produced. Their plant in Pune is located in a lively automotive hub shared with their six major suppliers. There is a clear effort put into sustainable production as the plant was dubbed as “zero discharge plant”. A very young workforce works in the Pune plant, whose age ranges typically from 22 to 35 years. |
| Tetrapak | Pune | The Swedish company Tetrapak has many production facilities across the globe, including one in Pune. They produce packaging material and straws that are then shipped out to customer’s production plants that fill the packages with different content e.g. juice. This is a typical process industry plant with high level of automation and highly skilled workers. |

Training facility at Tata Motors in Pune.

## INTEGRATED PRODUCT AND PRODUCTION DEVELOPMENT

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Integrated product and production development refer to the collaboration across the two disciplines. In the following sections, three challenges with integrating product and production development are discussed:

- Geographical distance - The geographical distance between product and production development affects communication frequency negatively.
- Cultural differences - Cultural differences affect communication content and format, and without taking this into account the risk for misunderstandings is significant.
- Organisation, workforce, and production preparation - Since Indian organizations tend to be more hierarchical than Swedish, Swedish organizations and engineers need to be more clear in their communication. Furthermore, product design must take into account a less automated production system.

### GEOGRAPHICAL DISTANCE

In Swedish companies with production in India, there is an improvement potential in the collaboration across product design and production development. One of the contributing factors is the geographical distance. However, the ambition to communicate across design and production is apparent in both Indian and Swedish organizations.

Geographical distance between product design facilities and production facilities comes with challenges. From what we have seen, two main company structures were identified: Swedish companies that have opened production facilities in India, and Indian companies with design and production facilities in India. The incentive for Swedish companies to invest in production facilities in India is evident because of the huge market. In addition, the strategic initiative “Make in India” has provided incitement for companies to produce products in India, rather than subsidising imported goods.

There are some examples of Swedish companies that have invested in production facilities in India. This type of separation between product and production development can lead to a lack of communication between different functions within an organization, as has been shown by Allen 1977 (Ulrich and Eppinger, 2008). Products are typically designed and tested in Sweden and teething issues are eliminated before production is set in place in India. Here, the geographical distance is a big challenge, when production issues needs to be resolved by design and information needs to be transferred to upstream activities. One company stated that problems in production had to be approved by the design office in Sweden before an implementation could be done. The effect is evidently increased lead times. However, many of the visited companies mentioned that they work in cross-functional teams to eliminate uncertainties across design and production. Yet, we did not manage to determine the current state of that collaboration.

### CULTURAL DIFFERENCES

There are cultural differences regarding communication of challenges and obstacles when introducing a new product in general, and this applies to communication between Swedish and Indian organizations as well. Due to some of these, it is not certain that a production team will speak up about issues or challenges unless explicitly asked. For example, the Indian organizations/teams/individuals tend to answer that there are no issues in production, because they believe that they are able to finalize the product in time and thus it is not an issue. This result is in a need for adaption; even with an explicit question, answers need to be taken with caution and questions need to be formulated differently in India compared to Sweden.

In Sweden, production departments are often involved early on in development and comments on possible challenges or obstacles within the project. The flat organization in many Swedish companies drive an open environment where issues are communicated and dealt with early on, while the more hierarchical structure in

Indian companies can result in a lower level of resistance or questioning from production departments. “It is easier to say yes and deal with the issues later” for some Indian organizations, as opposed to Swedish companies, where it is easier to voice concerns early rather than deal with consequences afterwards. This difference in communication also results in a lack of transparency for issues, since production facilities might take it upon themselves to solve issues that have risen. This is why it might be needed to reformulate questions regarding challenges from generally asking for issues or challenges, to instead demand a countdown of the biggest challenges for a given period of time.

The view on what constitutes an issue or challenge differs between India and Sweden. While Swedish companies might identify possible issues as challenges, an Indian production facility sometimes does not explicitly talk about something as an issue until they do not know how to resolve the situation.

A clear difference between Swedish and Indian production facilities is the approach to problem solving: Swedish companies take longer time to find a solution, in order to validate and make sure that the new solution does not affect other aspects of production. Indian companies, on the other hand, might find a solution quicker but with less validation work before implementation. This increases risks for new issues, while keeping downtime at the present production stop to a minimum.

### Organization, workforce, and production preparation

A designer or production engineer that comes in contact with an Indian manufacturing plant need to understand that they will have an authoritarian role towards operators. The company structures in India seem more vertical as opposed to the horizontal organizations in Sweden. Many Indian manufacturing plants are subsidiaries of foreign companies or manufacture to order from a foreign company, which makes them very dependent. Since these manufacturing plants are dependent in terms of technology, design, and regulations, they need to constantly perform and show good will towards their owners or customers. With a large and young population and a manufacturing that still holds many simple manual tasks it is easy to replace the workforce, which naturally keeps wages low. This leads to a situation where including everyone’s opinions and requirements in the product/production design might not be the number one priority. Furthermore, when designing for an Indian production system, the designer needs to consider that there is a lot more manual work in the production. Engineers designing products for Indian production facilities need to think differently when integrating production aspects in the design phases; design guidelines for assembly differs depending on whether the assembly is manual or robotised (Boothroyd et al., 2011).

The relatively vertical organizations can influence the product design and production development and design-production interface in several ways. These influences can be intensified in cases where the product is designed outside of India but produced by Indian companies. The challenges and opportunities provided by these influences should be investigated in more details to support and improve the product design and production development integration.

# DIGITALISATION

*Jon Bokrantz, Liang Gong, and Magnus Åkerman.*

Current digitalisation agendas, e.g. "Industrie 4.0" (Kagermann et al., 2013) and "Smart Industry" (Ministry of Enterprise and Innovation, 2016), involve a vast array of challenges along both hard (technological) and soft (social) dimensions. Therefore, these challenges concern both machines and humans, and production systems can be regarded as socio-technical systems. Automation in production can be divided into a mechanical part and a computerized part. The mechanical part aids the human in physical work (known as physical automation) and the computerized part aids the human in cognitive work (known as cognitive automation). In order to effectively realise cognitive automation, digital systems are required. In fully industrialised countries, production has experienced a shift from mass production to mass customization. An important enabler for this change has been automation, especially regarding information management and computerization of all phases in the production chain (Silveira et al., 2001). When systems grow more complex with higher diversity, more complicated products, and more connected technology - smart automation solutions will become even more important. Frohm et. al. developed this view of automation into a measurement framework called Levels of Automation (LoA) (Frohm et al., 2008), which served as the guiding framework for the observations in this section.

## SWEDEN

The Swedish manufacturing industry has relied heavily on automation. Robotic density can be viewed as an indicator for this, and recent data indicate that Sweden has 157 industrial robots per ten thousand employees in manufacturing (excluding automotive) compared to the world average of 66 (IFR, 2016). There is also an emphasis on achieving multi-skilled operators in Swedish manufacturing. For example, many companies strive to exploit a broad range of human capabilities in production as a mean to achieve flexibility. In addition, cross-functional collaboration, typically in teams, is commonplace in Sweden. In highly automated process industry plants, operator work tasks commonly include monitoring and maintenance. In discrete manufacturing plants, high automation levels are typically found in early phases of the production chain, e.g. foundry, press, heat treatment, machining, welding, painting. In contrast, the level of automation is generally lower in assembly systems and logistics where operators often work manually and with hand-held tools. Exceptions naturally exist, e.g. logistic systems with fully automated material handling using transportation robots. However, there has been a recent focus in both research and industry towards more dynamic automation solutions even for assembly systems. One economically viable solution is to focus on the cognitive automation and provide the operator with better information and support tools (Åkerman et al., 2016). Another approach is to utilize new low cost technology and design an environment where humans and robots collaborate (Fast-Berglund et al., 2016).

In general, despite rather low levels of automation in later stages of the production chain, Swedish manufacturing industry has a good position when it comes to digitalization and the fourth industrial revolution (Blanchet et al., 2014). In addition, the emphasis on industrial digitalization is strong on political and governmental level in Sweden (Ministry of Enterprise and Innovation, 2016, Produktion2030, 2016). This emphasis will most likely continue and shape the forthcoming efforts in Swedish research and industry. However, small and medium sized companies generally struggle in keeping up with this development. Many Swedish companies are more than twenty years behind in regards to their IT-structures with stand-alone systems and central databases. To be able to connect all products, machines, and humans to create Cyber-Physical Systems (CPS) and smart automation, the digitalization strategies need to focus on decentralization, interoperability and reducing complexity. In sum, the way forward for Swedish manufacturing industry is rather clear: ensuring competitiveness through extensive digitalization. However, there is a clear sense of urgency and thus a strong need for continuous efforts in both industry and academia.

## INDIA

Indian manufacturing is experiencing extensive growth as a consequence of globalisation as well as governmental initiatives like Make in India. Empirical research within Indian manufacturing has suggested that Indian companies give higher priority to quality management and lower importance to flexibility (Dangayach and Deshmukh, 2003). Less emphasis on flexibility could be a contributing factor to that automation has not yet played a major role in the growth and development of Indian manufacturing. As an example, the robotic density in Indian manufacturing is 2 per ten thousand employees (IFR, 2016). However, the number of industrial robots is expected to grow in India the forthcoming years (IFR, 2016).

During our trip to India, the LoA framework was used to observe levels of automation on an aggregated station-level. A summary of automation levels found within the visited companies is illustrated in Figure 2.

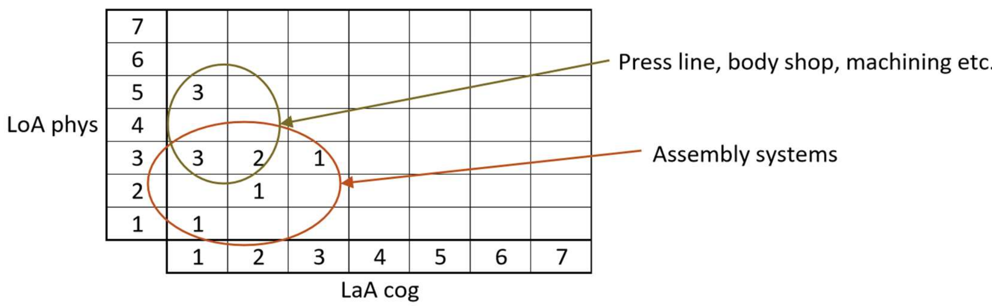



Figure 2: Average physical and cognitive levels of automation assessed from observations at the companies in India.

Physical automation levels are rather polarized within the companies, e.g. either totally manual (level 1) or static workstations (level 5). Examples of lower automation levels include manual production processes (e.g. assembly, welding, machining), manual material handling, and manual data collection and visualization. Examples of higher automation levels include SMT, moulding, and machining equipment, as well as typical automated processes found in automotive production (e.g. press shop, body shop, and paint shop). Cognitive automation levels are rather low, typically ranging between 1-2, i.e. totally manual (own experience) or decision giving (working sequencing). Examples include absence of work instructions and manual production planning. Few examples were observed for higher levels of cognitive automation. At present, these lower automation levels reflect the low number of product variants in production. In addition, this aligns with current availability and cost of labour. In addition to low levels of automation, there do not seem to be a strong emphasis on developing operator skill levels to achieve a workforce with greater multidisciplinary competence. For example, Indian operators were often found to be rather dedicated to specific work tasks. In sum, there seem to be a large range of physical automation levels in Indian manufacturing, whilst there seem to be a concentration on low cognitive automation levels.

In addition to shop floor observations, we identified promoting and hindering forces for automation. Production volume is the main hindering force for automation, a trend that can be found regardless of industrial branch or production layout and process. In most of the visiting companies, current volumes are too low to make automation investments economically viable. In addition, high availability of manual labour and low labour costs are two additional factors. Furthermore, many Indian companies wish to contribute to society by offering job opportunities, which strengthens the emphasis on manual work. Promoting forces for automation include global demands from customers and owners, e.g. a desire to have uniform global production process for specific products. In regard to automation strategies in India, the most common future plans were low cost physical automation, e.g. replacing simple, repetitive manual tasks with automated equipment.

## COMPARISON

In general, automation levels are higher in Sweden compared to India. This is likely to be influenced by differences in the business market (high cost mass customization vs. low cost mass production) as well as the labour market (low labour availability, high labour cost, and an elderly population vs. high labour availability, low labour cost, and a young population). In addition, there seem to be a stronger trend towards investing in higher automation levels in future Swedish production, particularly in regard to cognitive automation and collaborative human-machine systems. However, given the rapid economic growth and technological development, in combination with favourable demographics and supporting governmental initiatives, it is likely that levels of automation in Indian manufacturing will increase at a rapid pace in the future.

How automation is utilised by manufacturing companies can also be observed in how operators work. Romero et.al. (Romero et al., 2016) suggests four evolutionary steps of operator work in an "Operator 4.0 framework", as a reference to Industry 4.0. Operator 1.0 is pure manual work without any powered automation. The second step of operator support is computerisation, which means work with the aid of computer systems and programmable NC machines. With the introduction of industrial robots, human operator is aided with more flexible automation systems that can do complex material handling with dexterity. Operator 3.0 also include collaborative systems that is still very rare in the industry. Operator 4.0 is the Cyber-Physical and human-centred system fully implemented. A comparison between Swedish and Indian manufacturing from this human-centred perspective is illustrated in Figure 3.

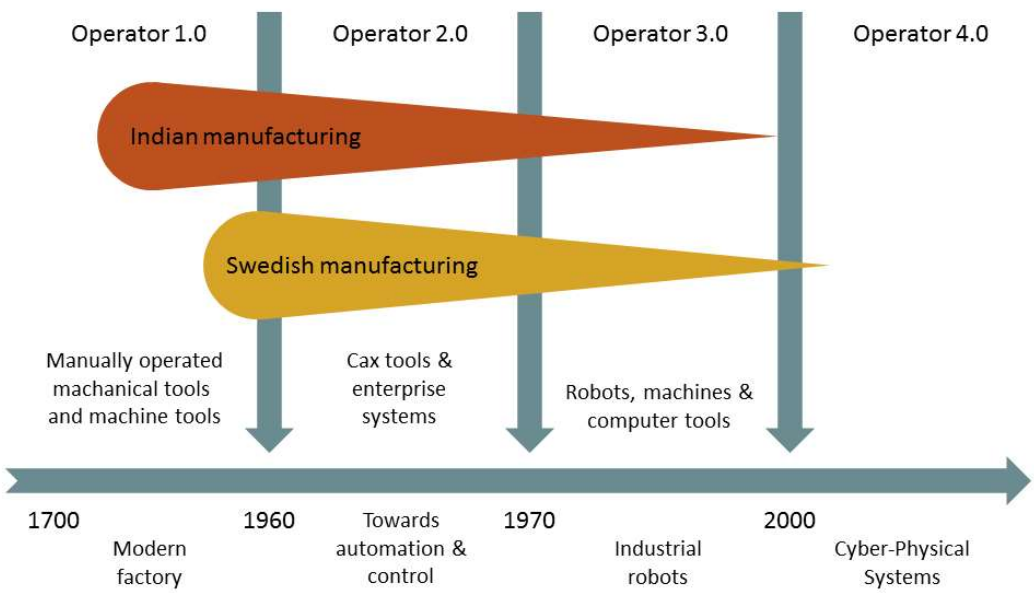
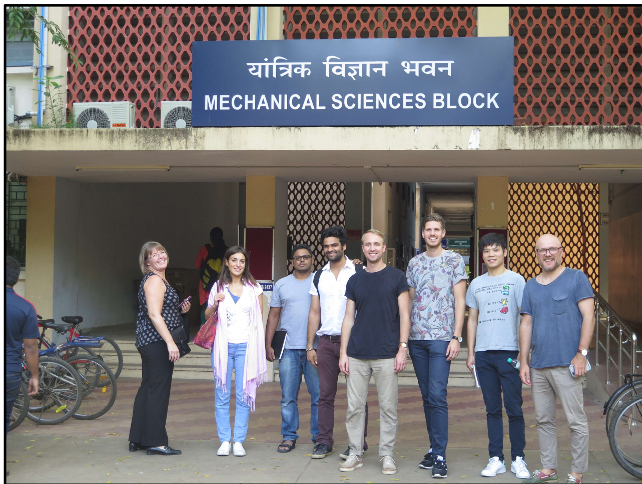



Figure 3: Observed differences of operator work at Swedish and Indian manufacturing companies in the evolutionary Operator 4.0 perspective (Romero et al., 2016).

## CHALLENGES FOR INTERNATIONAL PRODUCTION

- Automation strategies should take contextual differences in the global industrial markets into account (e.g. product types, business environment, and demographics).
- Changing from labour intensive to automated production: when production volumes, productivity requirements, and labour costs will rise in India in the future, appropriate automation strategies should be developed and implemented.
- Differentiation in production strategies: Sweden is more suitable for advanced mass customization whilst India is more suitable for cost-effective mass production.
- A major challenge in Swedish manufacturing lies in aligning information technology.




Manufacturing and engineering department at IIT Madras in Chennai. The huge campus was previously a national park which can be seen with its dense vegetation and rich animal life.

## PRODUCTION PROCESS

*Daniel Johansson, Mike Olsson, and Varun Gopinath.*

The aim of this focus group is to study different production processes and how it is used to meet market demands with regards to cost, quality and environmental impact in Sweden and India. The fundamental premise is that there is no "World Class Production" with optimal processes that will work globally. Each country has its own social, economic and environmental challenges that need to be tackled and each production system needs to be adapted to its location in order to utilize its full potential, as is visualized in Figure 4. This premise especially influences relocation of a manufacturing facility. Not all production systems are appropriate to transfer to a new geographical location and e.g. a high production performance might be the result of the personnel working at the current production site (Andersson et al., 2013).

To assess the production processes, in terms of technological development and general competence levels, machinery, methods, measuring equipment etc. was observed. The complexity of the parts being manufactured and assembled have also been of interest in order to understand production related challenges.

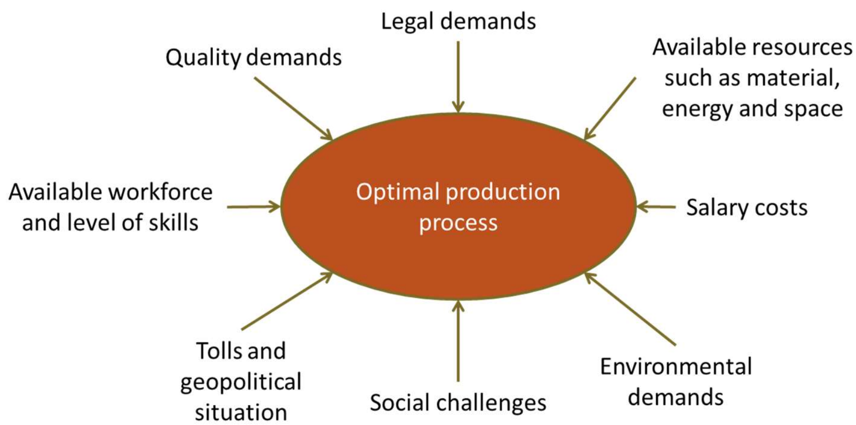



Figure 4: A number of factors influence the design of the production process in order to utilize its full potential dependent on where it is located.

### SWEDEN

The high salary cost is one of the biggest driving factors in Swedish production pushing for continuous improvements, automation, and reduced cycle time with new and/or improved production methods. Other factors that influence production systems, and the corresponding production method, are environmental impact, quality control, energy consumption, and factory floor foot print. Of increasing importance is also the work environment where job safety and ergonomics plays a big role in the design of the production systems. As skilled work force, such as operators and low-level management, are increasingly in short supply, salaries as well as the work environment play a large role in the design and choice of production system.

### INDIA

India is one of the largest economies with a fast-growing market which means access to personnel are no concern in India. Salary costs in India are low, often lower even compared to other large growing markets such as in China or Brazil. The low salary costs have a great influence on the production in India and in many cases companies focus on more operators and manual work instead of more advanced production processes. At a number of production sites in India it was noted that wastes such as quality losses, production rate losses and time losses are solved with adding more operators. Furthermore, instead of solving the root cause of the problem a temporarily solution is applied with a "quick fix".

Products produced in India have in many instances a low level of complexity e.g. brackets and less advanced mechanical components. In some cases, some more advanced components are imported and the assembly process are then carried out in India. This is mainly due to government regulations that taxes completely assembled products. For that reason, Completely Knocked Down (CKD) units are often imported to India to be assembled. There was also examples of components with low complexity that was produced in India and shipped outside of the country because of the complexity in the assembly process. Reasons for having a low level of complexity production or assembly in India can be due to education level, quality, safety or environmental issues.

## Comparison between Sweden & India

There is a big difference in the level of advanced machines and equipment between different companies in India. The range stretches from old machines from the 50-60's up to very modern machines equal to many Swedish companies. Older machines imported from countries like Sweden have been refurbished and are used in India when they no longer are cost efficient running in a Swedish factory and lack tougher safety regulations. It should be noted that these machines seem to support the Indian market and are cost efficient in their new location.

Depending on the manufacturing method, there are different ways to ensure the quality in a production. For one assembly operation, there are possibilities to use one tool to tighten several bolts in one operation where the torque of the bolts also is logged by the tool and stored for quality purpose, this have been observed in Swedish production. However, an observation from an equivalent operation in India, this operation was performed with a tool that is not able to log the specific torque, which is manually logged on a paper certificate and the bolts are colour coded to ensure that they have been tightened. Another example is related to welding of bigger parts. In Sweden, such operation would be fully automated with a robot. In India, the welding is often manual while the feed of the welding wire and output current is automatically controlled to ensure the quality.

Some of the companies in India made very large batches of material to be able to supply the rest of the production for several days or weeks. This can be related to problems with setup time or cost to change between different products being produced.

In general, the production and the production systems seem less flexible compared to Sweden and other western companies. Much of the production facilities visited were labour intensive with big batch sizes. This has been noticed in e.g. the automotive industry where the customer has fewer options to choose from, in terms of customizing a new car from factory, which also affects the design of the production system.

## Work Safety

Many of the visited companies in India highlight safety consistently and also information regarding safety processes is given to both employees and visitors. Working environment in general seems to have a prominent role at the manufacturing companies in India even though there are exceptions of production with restrictions in the western world that have moved to India because of stricter regulations (e.g. environmental).

The demands on safety on the production floor are derived from several factors such as the design of the production system and methods used, national-regulations, quality etc. From our observations, the demand on safety seems to be actively encouraged by the managements and certain facilities have been successful at conveying the importance of safety thinking on the production floor. However, the operators do not seem to be actively supporting this way of thinking and this could probably be linked to the relation between the management and factory floor workers. At one of the plant visited, we were told of the injuries that have occurred over the past few months and it seems that non-serious injuries occur fairly frequently and the serious injuries do occur regularly even with the safety processes in place.

## KEY PERFORMANCE INDICATORS (KPIS) IN PRODUCTION

*Carina Larsson, Ilaria Barletta, Maheshwaran Gopalakrishnan, and Sasha Shahbazi.*

A Key Performance Indicator (KPI) can be described as a measurement that shows how effective a company is achieving key business objectives as well as performing key operational objectives (Neely et al., 2002). In particular, KPIs being tracked in production environment, if well designed, can provide valuable information for driving continuous improvement (CI).

KPI monitoring and evaluation are of a paramount importance for understanding how production activities and performances are aligned to the company strategy. Is also important to the production strategy at a country level, which in our case are e.g. “Made in Sweden 2030” (Teknikföretagen, 2013) and “Make In India”.

We analysed what types of KPIs Swedish and Indian companies use at the shop floor and how they are displayed and communicated. The analysis was conducted according to these dimensions:

- Sustainability KPIs, i.e., economic (in this case, operations management), environmental, and social performances.
- Performance measurement and CI, i.e., KPIs tailored to CI improvement of operations at the shop floor.
- Preventive and corrective maintenance of critical machines.
- Visual management, i.e., the way whereby KPIs are displayed in the shop floor.

### SWEDEN

With respect to sustainability, the report “Made in Sweden 2030” (Teknikföretagen, 2013) claims that “in 2030, Sweden is a forerunner in sustainable production”. Sweden is putting effort into making this vision come true through several means, for instance by improving disassemblability and recyclability of products, recycling and reusing of materials, developing innovative sustainable business models and sustainable production system and investing in product innovation. Moreover, Sweden will need to work on developing decision support tools to assess risks of production-related scenarios in terms of environmental impact (Teknikföretagen, 2013). Sweden has introduced a list with 16 environmental quality objectives (The Swedish environmental protection agency, 2013) by focusing on a variety of environmental impacts such as climate change, air pollution, toxicity, acidification, radiation and clean water, among others. Production-related environmental objective has been also considered as international megatrends in “Made in Sweden 2030”. To stay competitive in the future, Sweden must cope with transition of the products, logistics and production systems as well as business models to not only comply with upcoming sustainable legislations but also to stay one step ahead of their international rivals. This includes higher efficiency and optimization in resource consumption, like energy, water and material, remanufacturing and recycling, LCA-based business models, and innovative new production methods like additive manufacturing and virtual manufacturing to influence supply chain and logistics. To achieve such a big goal, Swedish industry has broken down sustainability goals and strategies into sustainable KPIs on the shop floor. For instance, all the companies we visited in Sweden regularly measure environmental accidents. In addition, the KPIs themselves need to be assessed and changed in one-year interval with yearly goals and strategies. Sweden, as well as many manufacturing-focused European countries like Germany and Italy, needs to act now in order to contain the threatening effects of skill shortages in manufacturing because of ageing population (Berlin et al., 2013). In order to be competitive, companies need to focus on improving their production processes and surrounding areas, CI being a critical success factor for improved business results (Hyland et al., 2007). Follow-up and communication are critical success factors for a successful implementation of KPIs (Alaskari et al., 2013, Jayaraman and Teo, 2010). Follow-up of CI is not an easy task in Swedish companies, and often the CI KPI is specified as number of improvements per employee and year. Some companies also try to count pay-back from CI actions, struggling with guidelines of how to count what is gained from the improvement. Efforts are however made to integrate production KPIs and CI KPIs in order to improve business results in manufacturing companies.

From a maintenance perspective, Sweden is involved in creating service based strategy for maintenance for production system (Production 2030). Production 2030 has different areas of strength including “product and production based services” focusing particularly on maintenance. Based on our visits to Swedish manufacturing companies, the current maintenance practices are based on the developments of the previous two decades. However, on the research front, universities and manufacturing companies are working together to fill the gap between current maintenance practices and maintenance of the future, i.e. Industry 4.0 (Maintenance 4.0). Within this includes better KPIs for maintenance, qualification of the effects, data analytics, and data-driven decision making.

### India

With respect to sustainability, part of the vision of “Make in India” strategy aims to:

- “Create 100 million additional jobs by 2022 in manufacturing sector.
- Create appropriate skill sets among rural migrants and the urban poor for inclusive growth.
- Ensure sustainability of growth, particularly with regard to environment.”

India has been facing severe environmental issues such as air pollution, water pollution, and pollution of the natural environment. For instance, in November 2016, during our stay, all schools in New Delhi were closed for three days because of “levels of PM2.5, tiny particles that can clog people's lungs, were 90 times higher than the level considered safe by the World Health Organization” (BBC, 2016). The manufacturing sector has a great opportunity to help the government address these issues by monitoring factory environmental and social performances.

CI work was shown in almost all Indian companies visited. However, KPIs presented did not focus on CI. This might mean that CI was totally integrated into the production KPIs, or that CI KPIs were not followed-up on a higher level in the companies. Asking about and discussing CI KPIs with our hosts, the conclusion was that CI is run at basic level, focusing mainly on 5S and simple shop floor improvements, not followed up at company level.

## Comparison

In sum, Table 3 compares the main conclusions from the analysis addressing KPIs in production being monitored in in the shop floors of the Swedish and Indian companies.

#### Challenges in international production

- According to our experience and recent observations, monitoring and displaying KPIs at the shop floor is not enough. Engaging employees at the shop floor in the process of understanding KPIs for operations management, CI, sustainability and maintenance is challenging.
- Integrating CI measures into other performance measures is a coming challenge.
- The aforementioned need applies to KPIs related to environmental and social sustainability to.
    - For instance, with respect to India, if employees are aware of the pollution-related problems that the country is facing (e.g. in New Delhi) and the environmental impact of manufacturing activities, then it can be argued that employees will naturally feel motivated to understand the severity of environmental process and find out how to improve environmental performances. If proper incentives are in place, this outcome can be achieved quickly and effectively.
    - Safety in India was a deep-rooted concern, which is addressed by the management through models and codes of behaviour and theory-based training. We argue that having recurrent practical safety tests would allow Indian factories to decrease accident and fatality rates more than traditional learning already does.
    - We believe that social sustainability at the shop floor should be seen not only as a concern for occupational health and safety, but also wellbeing and empowerment during work time.
    - Environmental KPIs are usually measured for reporting purposes due to legislations and industry regulations e.g. energy and water consumption and waste generation. We believe that

more/better environmental KPIs need to be included for environmental improvement initiatives and not only complying with mandatory legislations. For instance, very few waste segregation and material consumption KPIs were found during our visits.
    - It was clear that environmental KPIs are communicated in a top-down approach: from environmental management to the operations; mainly due to current organisational structures (having few environmental coordinators). This structure should also include bottom-up approach to see what environmental requirements in a specific operation on shop floor exist.

- Indian companies need to build up an IT and data management infrastructure that allows an easy and up-to-date monitoring and navigation of KPIs in production, especially for KPIs related to operation management and maintenance.
    - With the ever-increasing production demands, such as volume and cost competitiveness, automation strategies will be developed and implemented in the future. Therefore, working on maintenance proactively will become a major challenge. Development of IT systems and data management will play a crucial role in this.
- We did not observe any visualization at the shop floor regarding the connection between KPIs and the overall company strategy, which is vital to keep a sense of “purpose” high all through the workforce.

Table 3: Comparison of Swedish and Indian approach to KPIs selection and display in the shop floor.

| DIMENSION OF ANALYSIS | SWEDEN | INDIA |
|---|---|---|
| **Operations management KPIs** | No significant differences have been observed.<br>Operations management KPIs refer to performances such as safety, quality, delivery, cost, people and productivity/efficiency and the display of them through charts or color-coded boards is vastly diffused. | |
| **KPIs for CI** | KPIs for CI refer to lean production (e.g., tact time) value stream and progress being made in CI. | From a reporting perspective, KPIs for CI were not dissimilar from the ones being adopted by the Swedish companies. CI was displayed through 5S score in many cases. However, the integration of CI practices into operators’ daily work can be improved. |
| **Environmental KPIs** | Environmental KPIs are mostly focused on energy and water consumption per unit of product and amount of waste. They are well understood on the shop floor of the Swedish plants, even though they still represent around the 5% - 10 % of the total amount of production-related KPIs according to what has been observed. | The use of environmental KPIs is still sporadic on the shop floor of the Indian plants (with some noticeable exceptions), unless they belong to a Swedish company. In this last case, they mainly consisted of energy or water consumption per unit of product and amount of waste as well. |
| **Social KPIs** | No significant differences have been observed.<br>Social KPIs are focused on occupational health and safety for the most. | |
| **Maintenance KPIs** | Maintenance is CI-oriented<br>(e.g. better, preventive maintenance, improvement of reliability) and KPI values are being followed up. | The maintenance policy is largely reactive during production time. KPIs are mostly reduced to safety and environment KPIs. KPI values can’t be easily followed up because of lack of proper no data management (e.g., MES) systems. |

Right: Company visit at TetraPak in Pune.

Below: Mini conference at CPDM at Indian Institute of Science in Bengaluru.

Traffic in many larger cities in India can be extremely problematic. Especially in Bengaluru that is growing so rapidly.

Two-wheelers are popular because of the traffic. The picture above is from a parking area at the central station in Bengaluru.

## INTER-ORGANISATIONAL COLLABORATION

*Pierre Johansson, Lisa Larsson, and Farhad Norouzilame.*

This section discusses strategies for global production and different forces promoting or hindering inter-organisational collaboration based on visits in Swedish and Indian manufacturing plants. The main conclusions are provided in the following bullet list:

- Knowledge transfer is the main purpose of having an International Manufacturing Network (IMN) consisting of multiple plants close to the local markets. Without knowledge transfer, there is no chance of creating synergies.
- It is essential to have clear guidelines regarding the autonomy of plants within an IMN that help to prevent further conflicts due to lack of coordination.
- There are major cultural differences, which require subsidiaries belonging to foreign countries to invest in CSR and local adaptions to perform as desired in their IMN.

### KNOWLEDGE TRANSFER

To make the most of the strength of all plants in an IMN, it is necessary to transfer knowledge by moving key persons between plants in order to share knowledge, values and to spread culture.

#### EXPATRIATES

Swedes to India: Except one of the plant managers, we did not see many Swedish expatriates in the subsidiary plants of Swedish companies in India. That being said, the people whom we met stated that the Swedish experts were available on site in India during the installation and ramp-up phases.

Indians to Sweden: It was interesting that a few managers in certain Indian plants had lived in Sweden for a while or at least were commuting to Sweden a few times. This was particularly valuable as they had grasped a part of the culture in Sweden - values, quality and etc. This was clearly visible and was reflected in their vision, how people were treated and inequality issues.

#### COMMUNICATION

The choice of communication channels and medium used might change over time considering the recent development in communication technology. Nonetheless, the purpose is to deliver the right information to the right parties in the network. The vital point is to create a model of communication that could lead to a balance in efficiency and effectiveness of the knowledge transfer.

Monthly virtual meetings with all of the quality managers of all plants were also held; here, the agenda covered network issues, the performance of each plant, trends and best practices. Several cross-factory teams were formed on certain competences such as heat treatment, engineering, project management, etc.

#### COMPANY SPECIFIC PRODUCTION SYSTEMS (XPS)

The foreign subsidiaries of the Swedish plants we visited in India had a clear strategy regarding the implementation of their company XPS in their Indian plants. They had a central team (organization) in Sweden where XPS was continuously developed. In each plant, there was a coordinator connected to a local team in the plant, that were responsible for understanding and transferring the XPS knowledge as well as implementing it in the plant. We did not discuss the success rate of how those plants implemented their XPS within their organization; however, in Volvo's plant in India, there was some mentions of a plant classification based on the level of XPS dissemination i.e. Bronze, Silver, and Gold.

### COMPANY CULTURE

Gruenter and Whitaker say that "the culture of any organization is shaped by the worst behaviour the leader is willing to tolerate." According to Hofstede (2001), a work culture can be divided into individualism and collectivism. In an individualist culture the work force is expected to be self-interest oriented and act accordingly, while in a collectivist culture to be focused on the group rather than the individual. During the study visits, both individualism and collectivism cultures were present which is also mentioned in empirical studies by Hofstede (Hofstede).

This is also related to the level of autonomy of the plant that is accepted by the company. The level of indulgence is considered low which means the Indian society is strong against impulses. This low level of indulgence does also affect the business success dependent of the culture, values and whether it is an Indian subsidiary or an Indian company. The difference in masculinity between India and Sweden is extreme. This high scoring of masculinity in India confirms the observed competitive mind-set the general society showed during our visit in India. This mind-set causes a variation of achieving competitive advantage between Indian and non-Indian companies due to those preconditions that are evident.

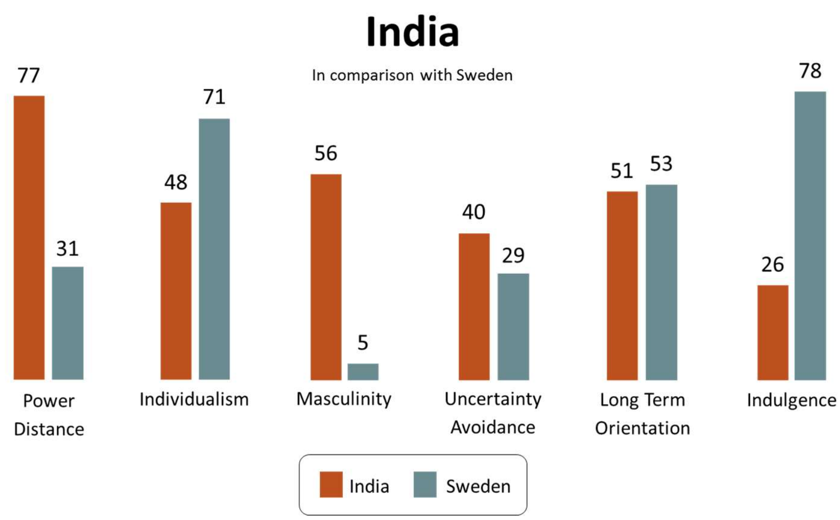



Figure 5: https://geert-hofstede.com/india.html in comparison with Sweden.

### COMPANY CORE VALUE

During the visits at the case companies it was interesting to see how western companies that manufacture products from the premium segment, educate their operators about product quality and safety. Due to cultural standards and economical prerequisites, the traditional operator does not share similar standards as in terms of perceived quality etc. in comparison with western cultures.

A main difference between a Swedish and an Indian operator is the level of education and standards of living. Corporate Social responsibility (CSR) becomes a central part for companies operating in this setting. In India, especially at Indian subsidiaries, it is common to have CSR programs. At one of the case companies, they focused on educating the society in traffic safety to get more people to choose public transportation instead of the less safe motorbike/scooter without wearing a helmet. Another example on CSR comes from TATA motors. They have a school with the aim to supply their factories with a trained work force, which is free of charge without obligations to continue working at the company after graduation. The value of such an initiative is not only advantageous for the company itself, but also for the industry in general where the workforce of trained operators is increased over time. Furthermore, the companies know that if they invest in the society and make the daily life easier for their potential workforce, they will benefit from it by getting higher production quality with less production disturbances.

## PLANT AUTONOMY

Coordination, together with configuration of an IMN are two main dimensions of IMN management. Autonomy is an important aspect of IMN coordination. To avoid uncoordinated decisions that may result in economic loss and conflicts within an IMN, it is of utmost importance to specify clear guidelines on the responsibility span of the plants on different areas. One area is the competence bundle i.e. the determination of competencies of a plant in production, taking supply chain responsibilities, and development of products and production systems (see Figure 6). Another significant area is the coordination responsibility of a plant that means the responsibility of a plant within an IMN in network activities such as knowledge transfer etc.

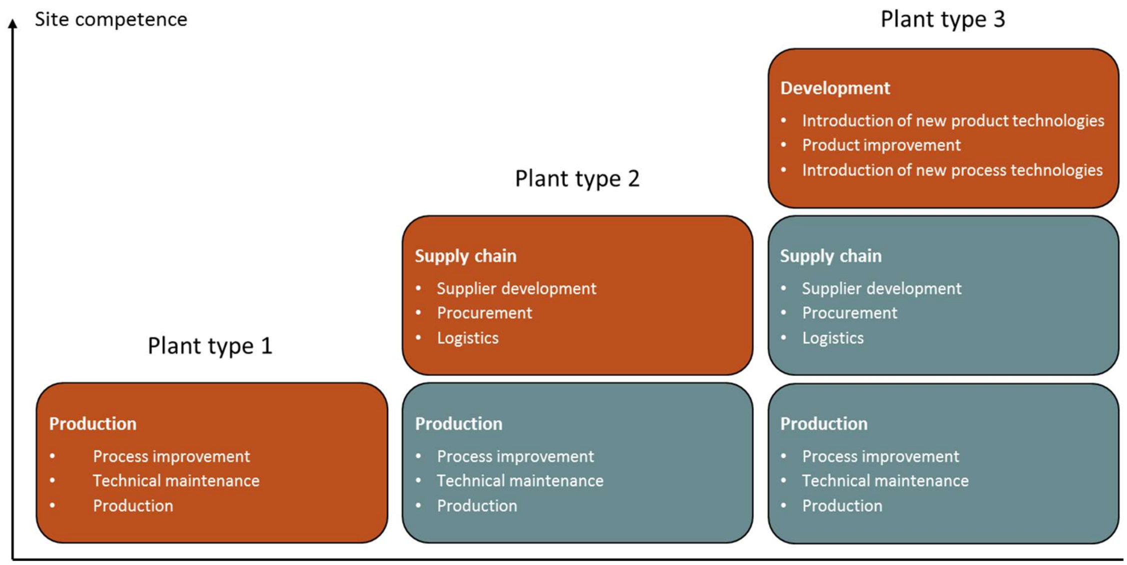



Figure 6: Plant types according to Feldmann & Olhager (2013).

### INDIAN SUBSIDIARIES

An interesting topic in the management of IMNs is the autonomy level of each plant in the network. In other words, what is the responsibility span of each plant in contribution to the vision of the company. Determining the responsibility span and autonomy level of each plant could lead to preventing internal misunderstanding and wrong expectations within the network. This becomes particularly important when plants in different countries, with different cultures are established or acquired. When it comes to the competence bundles mentioned earlier, it is important to determine how much the subsidiary plants can/should decide and how much autonomy/support lies on the shoulders of the headquarters. In literature, there are models that discuss and elaborate this matter. The ‘plant role’ model by Ferdows (1997) and the 'competence bundle' model by Feldmann and Olhager (2013) are among those.

During our visits, we visited two types of plants i.e. plants locally designed or centrally designed through headquarters. Some of the companies implement a standard solution and the focus of the local plant is to operate. One of the case companies illustrated how they had built up their production environment as a Tier 1 supplier and then expanded their production volumes through contracts with new OEMs. Another company was both a supplier to OEMs but also supplied own products direct to the market. Another visited manufacturing plant illustrated how their focus on merely operation had helped them to become among the top performers within their IMN. Examples from the study visits showed different aspects on plant autonomy. Some of the visited plants displayed a mixture of autonomy and dependency; manufacturing equipment was decided on a global level, while the manufacturing process itself was locally adapted. In some instances, the plants followed the global standards of their mother company.

### Indian companies and plants

Unlike Indian subsidiaries of foreign companies, the Indian companies have full responsibility for R&D, manufacturing and business development. For example, one particular case company that we visited was a Tier-1 supplier to Indian companies and subsidiaries of foreign companies in India. This company both had pure Indian companies and global OEMs as customers.

### Swedish companies and plants

Swedish manufacturing is often characterized by high level of R&D competence. Generally, of the visited companies in Sweden with plants in India, they usually have their R&D located in Sweden with strong collaboration with the local plants. Swedish manufacturing is also in general characterized by resource efficient manufacturing with a high level of automation to reduce repetitive work in their manufacturing processes. In Sweden, several of the visited companies have located production of complex and customized products in the home country while production in Indian plants are more focused on basic products and basic configurations of the products.

### Autonomy and Innovation

Innovation relies on a balance between control and autonomy in an organization. Autonomy can exist in different levels; a plant can be autonomous in a manufacturing network and individuals can be autonomous in a plant. The balance between autonomy and hierarchical control on a plant level influences the plant's possibilities to be innovative. A plant solely focusing on delivering according to targeted KPIs and relying on HQ for any developments will unlikely be very innovative. Autonomy on an individual level will influence employee innovation. Since Lean and CI were major parts of many plants, employees were expected to contribute with suggestions for improvements and take part of improvement work. We wonder though, if the employee attitude in some cases were to deliver the expected number of improvement ideas rather than aiming for improved production.

## CONCLUSIONS

The International Production course has gained a unique insight on globalization in manufacturing by visiting and comparing production facilities in Sweden and India. In one end, extraordinary differences have been observed between two countries with vastly different economic, ecological and social conditions. In the other, an array of similarities has been experienced that points towards that many aspects of globalization in manufacturing are fundamentally equal in both developed and developing countries. From the five different focus areas, the following conclusions are drawn:

**Integrated Product and Production Development**

- The geographical distance between product and production development affects communication frequency negatively.
- Cultural differences affect communication content and format. Without taking this into account, there are significant risks of misunderstandings.
- Indian organisations seem more hierarchical, whilst Swedish organisations seem more flat. Therefore, Swedish engineers need to be more clear in their communication. In addition, design engineers must take into account less automated production systems in Indian manufacturing.

**Digitalisation**

- Automation levels are in general higher in Sweden compared to India, which are dependent on several factors (e.g. business and labour market).
- The main direction of Swedish manufacturing is to ensure future competitiveness through extensive digitalisation. There is a clear sense of urgency and a strong need for continuous digitalisation efforts in both industry and academia.
- Sweden is more suitable for advanced mass customisation whilst India is more suitable for cost-effective mass production. These differences must be accounted for when developing and implementing automation strategies.

**Production Processes**

- Production systems seem less flexible in India compared to Sweden, where many visited Indian plants were labour intensive and utilized large batch sizes. This is likely related to lower complexity in products produced in India.
- In general, Swedish production systems utilized more advanced machines and equipment. Older machines from e.g. Sweden can be refurbished and used for cost-effective production catered to the Indian market.
- An emphasis on safety in production is prevalent in Sweden and India. Whilst it is often permeated to all company levels in Sweden, operators in India were observed to not always actively conveying the importance of safety thinking.

**KPIs in Production**

- Generic operations management KPIs are used in a similar fashion in both India and Sweden, such as displaying measures for e.g. safety, quality, delivery, cost or productivity on visual boards on the shop floor.
- Energy and water consumption were the main environmental KPIs in both Sweden and India, but the use of such measures on the shop floor seem to be more sporadic in Indian companies.
- There is a potential for Indian companies to develop IT and data management infrastructures that allows for monitoring and navigation of KPIs in production.

**Inter-organisational collaboration**

- Knowledge transfer is the main purpose of having an International Manufacturing Network (IMN) consisting of multiple plants close to the local market. For companies acting on both Swedish and Indian markets, knowledge transfer is essential for creating global synergies.
- Guidelines for autonomy of plants within an IMN that span across both Sweden and India is essential to prevent conflicts due to lack of coordination.
- There are major cultural differences between Sweden and India, which require subsidiaries in foreign countries to invest in corporate social responsibilities and local adaptations to perform as desired in the IMN.

As an ending note, the Swedish and Indian manufacturing industries are both facing an exciting future that holds both shared challenges and divergent directions. Still, the two countries have much to learn from each other, and continued collaboration on operational, tactical, strategic and governmental level is of great importance for the well-being of globalized manufacturing. We, PhD students and leaders of the Swedish Production Academy, look forward to a bright future where Sweden and India share visions, strategies, knowledge and technologies, and strive for competitiveness as partners, competitors and peers.

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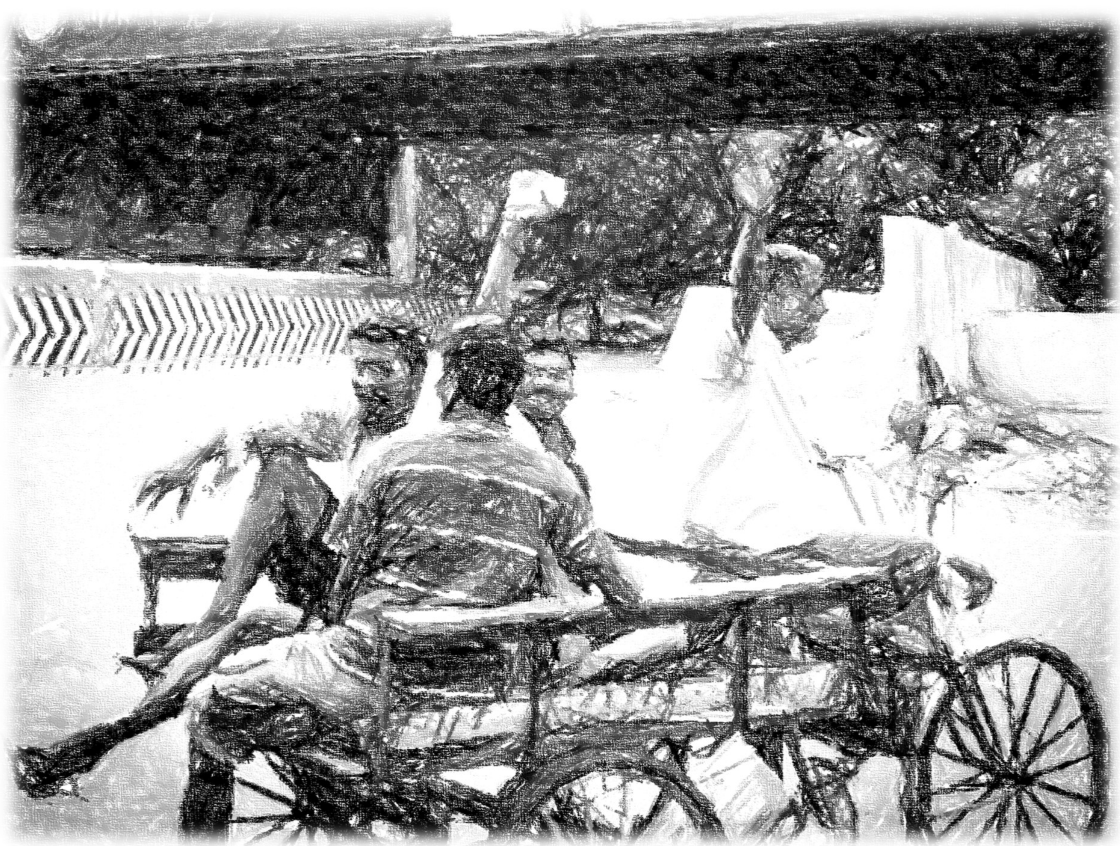

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