SMART FACTORY

GROWTH THROUGH COLLABORATION AND TECHNOLOGY

SMART FACTORY

THINK GLOBAL. ACT LOCAL.

THE SMART FACTORY

Innovation and growth in small and medium sized companies

Preface

In 2013 The Danish Industry Foundation (Industriens Fond) in collaboration with (SDU) University of Southern Denmark - The Mads Clausen Institute - launched the research project Smart Factory (SMAF). The project is part of the program related to challenges for suppliers in a global world. The project focused on investigating factors that would enable companies to establish a new platform for collaboration on innovative projects, and with advanced production technologies foster innovative products and production solutions.

This booklet targets industrial partners and policy makers and aims at dissemination of the projects' key results. In sum, the project is documenting the challenges and competences found in small and medium sized enterprises - SMEs - in the region of Southern Denmark. The booklet will introduce guidelines for how collaboration and smart technologies, can help SMEs to increase their competitive advantages in lean automation and digitalization in the direction of globalization and the so-called 4th industrial revolution.

The project has been executed from 2013-2016 and has been managed by (SDU) University of Southern Denmark - the Mads Clausen Institute together with the Mechatronic Cluster Denmark, Delta, CLEAN and a number of SMEs in the region of Southern Denmark. The majority of the funding for the project has been aimed at a PhD researcher, where a PhD thesis will be available in the Summer of 2017 with more details about inter-organizational collaboration.

The partners behind the project would like to express gratitude to The Danish Industry Foundation for the financial support and continuous exchange of viewpoints throughout the project. Also a warm thank you to the project partners Mechatronic Cluster, Delta and CLEAN.

We also want to express a huge thank you to the SMEs and organizations that have been involved during the project:

- **Hannemann Engineering**
- **Pehama**
- **OJ electronics**
- **Banke Accessory Drives**
- **Automatic Syd**
- **Alsmatik**
- **Focon**
- **Lodam**
- **Servodan**
- **Danfoss Power Electronics**
- **Eegholm**
- **Sønderborg Værktøjsfabrik**
- **Attec**
- **LH Equipment**
- **Brdr. Hartmann**
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- **Danrobotics**
- **Core Path Robotics**
- **Teknologisk Institut**
- **Force Technology**
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- **SP-stål**
- **Sønderborg Vækstråd**
- **Sønderborg Iværksætter Service**
- **Udviklings Råd Sønderjylland and Robocluster**

Furthermore a heartfelt thank you for the good collaboration in the project team consisting of:

- **Arne Bilberg**
  Associate Professor PhD SDU – SMAF project launcher and manager
- **Agnieszka Radziwon**
  SDU; PhD student financed by the project
- **Marcel Bogers**
  Associate Professor PhD; SDU (now KU)
- **Alexander Brem**
  Professor; SDU
- **Fei Yu**
  Assistant Professor PhD; SDU
- **David Grube Hansen**
  Research assistant, now PhD at SDU
- **Erik Skov Madsen**
  Associate Professor PhD; SDU
- **Lotte Gramkow**
  Senior Project Manager; CLEAN
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  Site manager; Delta
- **Kurt Fredrichsen**
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INTRODUCTION

A large part of Danish Industry is based on Small and Medium Sized Enterprises (SMEs), which account for 99% of the companies in Denmark and about two thirds of the job positions (source: statistikbanken.dk) . That is why, it is so important also to focus research and development at SMEs, and to target their challenges and ensure sustainable growth and business in these enterprises.

Therefore the focus of the Smart Factory project was to support the growth and sustainable development of the small and medium sized manufacturing industry in Denmark. The project focused on SMEs and how to improve their innovation and competitive advantage by focusing at their competences, strengths and opportunities. The project suggests innovative solutions and business models through collaboration and use of new technologies.

In the Smart Factory, SMEs should be able to collaborate on new products, markets and production or supply chains in a creative organization. The Smart factory is supposed to be organic, meaning it is able to reconfigure and adjust to new projects and customers and has to be seen and taken as a model for inspiration to manufacturing businesses in general.

The project takes into consideration Danish industrial culture, which is widely based on SMEs that by nature are very different, but also very flexible and lean in their way of operating. It has been very important to maintain this flexibility and freedom to navigate within their domains, and at the same time get the opportunity to join and collaborate in a bigger forum to become more powerful in a competitive and global environment.

THE SMART FACTORY IDEA

The SMAF project is based on innovation and growth through collaboration and use of new technology. Many SMEs are individually doing very well, but the assumption was that together they will do even better! The focus has been the region of Southern Denmark, but the results are transferable to other areas – in Denmark and abroad.

SMEs with complementary competences, technologies and markets may be able to increase their competitive advantage, if they jointly develop new products, productions or organizations. Many SMEs are component suppliers, but through collaboration they may be able to develop own products and productions to obtain a more global business model. SMAF stimulates entrepreneurship among SMEs, which may be the next step for established businesses to create growth.

The Smart Factory concept was first introduced in Germany 2010 as "Smart Factory—Towards a factory-of-things" by professor Detlef Zuehlke, where a physical high-tech production line was established. We conceptualize the Smart Factory as both a physical and a virtual space, where resources and competences are shared; and where communication between technology and people is very important. The Smart Factory is technology based and automated, but the employees play a major role. We do not talk about the unmanned factory; the employees play a very central role in the Smart Factory, where we see collaboration among people and enterprises. Technology is the enabler in collaboration with people to foster a flexible, adaptable and sustainable production.

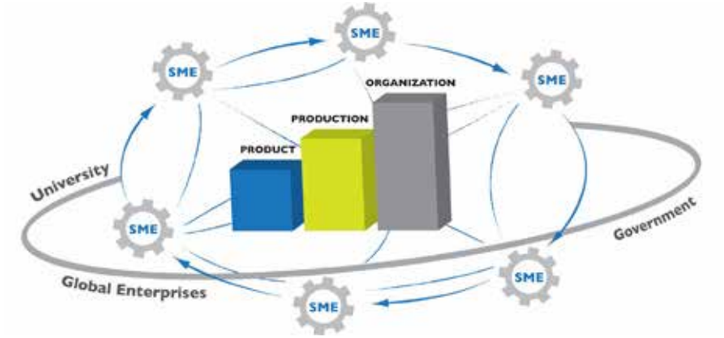


Figure 1: The Smart Factory idea is innovation and growth through collaboration and new technology.

In the Smart Factory we take into consideration the triple helix stakeholders including companies, knowledge institutions, supporting organizations (governmental and non-governmental), as illustrated in Figure 1. The idea is to think innovation in an open innovation environment, where SMEs collaborate to create new products, production concepts and organizations that can stimulate growth within a region or an ecosystem, where we find the right ingredients and energy for creating growth.

In the project we define the Smart Factory as:

"A Smart Factory is a manufacturing business that provides flexible production processes based on collaboration between enterprises and individuals, and where technologies may support the collaboration and production."

THE RESEARCH PROJECT

The initial investigation started with exploring the local firms in the region of Southern Denmark, that were part of various cluster centered activities. In the perspective of a regional innovation system clusters are often part of a political agenda, yet we quickly identified that what we were dealing with was an organically grown ecosystem. In an ecosystem companies will collaborate and grow regardless of forming clusters. The literature about ecosystems, as well as open innovation perspective, helped us in establishing the initial research design.

The major part of the research was performed through a PhD project, which tried to investigate:

How does intercompany collaboration contribute to the development of a local ecosystem in a particular region?

The research started from firm level and moved to interfirm level. There is a strong multilayer structure that impacts on personal level, which is different and concluded to be much more intense in a geographical small place like the region of Southern Denmark.

We concluded that interdependencies and ecosystem embeddedness constitute very influential factors that may have a huge impact on e.g. lowering transaction and coordination costs, as well as supporting external knowledge sourcing. Therefore it may be something that large cities may not be able to provide in the same way, unless there is an ecosystem with similar boundary conditions as to our research set up.

The research confirmed that in this local ecosystem there is already a high degree of co-evolution of firms. Companies support each other and proximity, mindset and alignment means a lot. In larger cities it may work differently, due to fewer interdependencies, easier exchange of suppliers, if the current ones are not sufficiently good etc. In the investigated ecosystem all members have strong incentives to play fair; they may need the other companies in the future.

Challenges and competences for SMEs

Based on our analyses it is concluded that at the firm/company level, the biggest challenges are sufficient size and power to scale operations. Another big challenge is lack of resources i.e. financial, equipment as well as manpower. Finding people with the right skills/competences and keeping them in the region is seen as a challenge, often there is a need for specific competences, but not necessarily at a fulltime basis and therefore sharing resources may be an interesting collaborative initiative.

If small firms would like to internationalize, it is a challenge to establish new relationships. Many firms see a challenge in taking risks and in being first mover to a new market. A challenge is to brand their products, big companies are well established and known in the market, where it may be hard for SMEs to penetrate.

At the inter-organizational level, one of the challenges may be power balance. If smaller companies collaborate with bigger companies, the decision power may be unbalanced. This may create tensions, so collaboration between more equal partners is found easier and more fruitful.

Challenges

- Size
- Scale
- Manpower
- Power balance
- First mover risk
- Absorbing new technologies

Competences/Strengths/Supporting factors/

- Strong technology focus
- Openness – “out of the box thinking“
- Good networking (formal/informal)
- High quality of products and services
- Proximity to research institutes, govermental institutes
- Presence of large firms
- Cooperation and competition

The firms have product and solution specific competences and they master their current technologies. The firms are generally very open, when they co-work, and are good in ‘out of the box’ thinking. They are good in networking, finding partners and local outsourcing.

Besides, investigated companies have very good networks, both formal and informal. What is more, they have very reliable supplier networks. High quality products and services give good references and customers are coming back. An important supporting factor is proximity to knowledge/ research institutions to get support. This is not only the university, but also good local government, entrepreneurial institutions (Sønderborg Iværksætter Service - SIS, Idea house, etc.) and facilitators like CLEAN, Sønderborg Vækstråd, Udviklingsråd Sønderjylland – URS, etc.

The local ecosystem

Ecosystem literature distinguishes between different types of ecosystems (e.g.: business, innovation, knowledge and entrepreneurial). Ecosystems are based on triple helix elements, see Figure 2, which refers to the relationship and collaboration between 1) industry, 2) research institutes, 3) governmental/non-governmental institutions. Others also talk about the society element in quadruple helix, the presence is crucial in e.g. living labs.

The presence of an orchestrator to motivate the ecosystem is not a must, but in the ecosystem in the actual region, the company Danfoss may be a typical orchestrator. Danfoss may set a direction, but SMEs also contribute to create growth and keep the ecosystem alive.

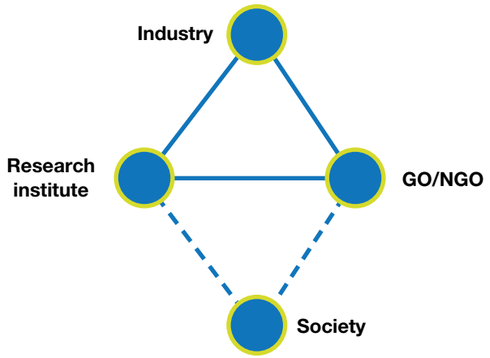


Figure 2: Triple Helix in ecosystems

The empirical study began with open innovation as framework. Figure 3 shows the outline of the empirical investigation, where the main research design conditions that demarcate the ecosystem are: 1) **Proximity** geographical and cognitive (i.e. related to the way we think, see similarities, approach customers), 2) **Interdependencies**, in a smaller region the stakeholders are more interdependent with lower incentives to inappropriate behavior, 3) **Co-evolution** where companies help each other, as well as 4) presence of an **orchestrator**.

The main research findings are explained through the lens of transaction cost, localized learning and resource based view.

4 conditions:

- Proximity (geographical + cognitive)
- Interdependence
- Co-evolution
- Presence of orchestrator

Open innovation phenomenon

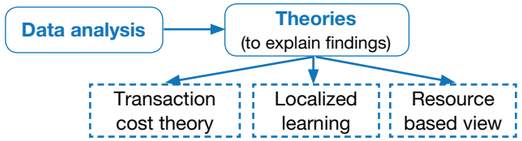


Figure 3: The Ecosystem prerequisites

Transaction cost.

Transaction cost means cost for searching partners, cost for doing contracts, etc. In the regional setup we observed relatively low transaction, because of local search for partners. Collaboration is based on trust; there are more informal agreements (because companies know each other). A high level of local support is observed, joint incentives to grow from knowledge institutions and regional councils. What is more, we did not observe any problems with intellectual property rights, a company will e.g. automatically be excluded from the network, if they behave unfair or they cheat. Companies just start to collaborate to see how things evolve, and then property issues are handled later.

Low transaction cost imply:

- easy search (networks and recommendations)
- low propensity of improper opportunistic behavior
- low transaction cost and higher credibility between companies
- informal agreements and collaboration
- big local support (incentives to grow from university and governmental institutes)

Localized learning.

Knowledge is openly shared, which is important for co-evolution. There is a common language and an alignment; this makes stakeholders cognitively much closer. The firms are opening up for external inflows and outflows of information.

Observations from the project:

- knowledge stays in the region
- knowledge is openly shared and transferred through people

Resource based view.

Companies are special, but at the same time they complement each other also by the resources they have (human, equipment, knowledge, etc.).

- specialized area with firm specialized knowledge
- specific resources
- open for external knowledge and resources
- cooperation and coopetition as a sign of openness

Collaboration ingredients

From the research findings, the ingredients and drivers for collaboration are found to be as illustrated in Figure 4.

Figure 4: Collaboration ingredients and drivers

Power balance is important (size of the firms, type of partners (Industry, University, GO/NGO) as well as **Shared incentives** and commitment to join, so that all partners will benefit and for all of them it would make sense to join. There may be different **Types of agreement**, formal or informal, and it can often evolve from informal into formal later, typically when money will be involved. In any collaboration it is important to have clear and realistic deliverables. **Goals/expectations** have to be clear and realistic for why we are doing it, who will like to buy it in the future, how could we characterize potential market and customer? Finally importantly **Ressources**, who has the necessary competences/knowledge/resources and may there be a need for external funding, in this case who may support. Last, but not least, **Leadership**/facilitation/coordination has to be agreed, should it be by someone that is known (familiarity and trust), or independent (university, intermediary, consultant).

Having the right ingredients is important to start collaboration, but to get the ecosystem and projects to grow, the drivers are important and the fertilizer to get a sustainable collaboration model.

Modules and frameworks for collaboration

Within the scope of the Smart Factory project researchers investigated issues regarding collaboration. It was found that there may be 3 overall purposes or models for collaboration:

- **SHARING** mostly related to sharing resources or equipment, so that SMEs are able to help each other with bigger investments that are too big for one company to handle, and therefore they make a common investment in resources that may be used and shared by more partners. This may be technical equipment or human resources.
- **CRITICAL MASS**, where more companies are joining forces to obtain sufficient power and capacity to solve a complex task or a big order, that none of them can handle alone. It may also be competitors that understand and see the benefit to be able to deliver a bigger task in collaboration.
- **DYNAMIC ORGANIZATION**, where companies collaborate on different projects in dynamic organizations across companies. From a pool of companies within the ecosystem, there are created temporary collaborations for a period of time to solve a specific task. The reason for this collaboration may be complementary competences, where complex tasks can be solved in collaboration, that none of the individuals are able to handle alone.

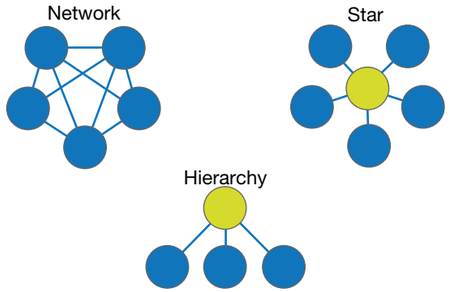
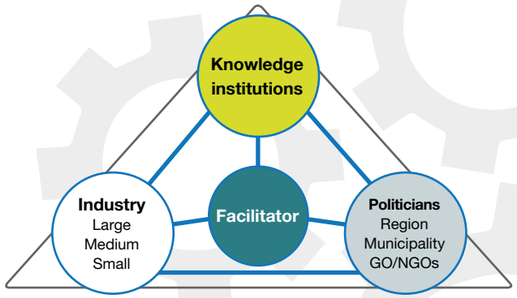


Figure 5: Three generic models for collaboration.

Ideal organizations for collaborations are not observed, because each project has its own characteristics, requirements, etc. The basic organizations may be described as the Network, Star and Hierarchy as illustrated in Figure 5.

In the **Network** model all partners are even and communicate directly to each other. In the **Star** model a leader/facilitator is handling all communication and collaboration is through the star partner. In the **Hierarchy** model the lead partner is contracting with other partners and may be acting as an orchestrator.

The framework for collaboration in the ecosystem may be the triple helix as discussed above and illustrated in Figure 6. In the triple helix framework the collaboration could be between all or some of the 3 stakeholder groups. If there is a need for a facilitator, it may depend on the individual project. A facilitator is here defined as an administrative organization that perhaps applies for funding and administrates the project during operations. An orchestrator on the other side is a body, typically a company or knowledge institution, that drives the development, and who is often major responsible for the project outcome. Neither a facilitator nor an orchestrator are required, in some cases both are present, while in other cases it may be the same stakeholder.



Figur 6: The Triple Helix framework for collaboration

The global view

Ecosystems in e.g. Holland also talk about large companies; here Philips operates as an orchestrator. When Philips had problems years back, local companies supported for their own survival, because if Philips went bankrupt, small businesses would probably follow. The SMEs started to support each other, and they were not afraid about letting ideas go.

In France, initiatives are predominantly coming from governmental initiatives. Therefore they are more into clusters than ecosystem. **Clusters** are not bad, but it is more **top down** based on political agendas.

Some of the interviewed SMEs in this research had international collaboration with Chinese partners. Along with the rapid development in China over the past decades, the economic structure in China has dramatically changed. Sønderborg has established very close relationship with Haiyan, the two cities have reached EU-China partnership agreement in 2013 and sister city agreement in 2016. This opened the door for many other possibilities, especially for SMEs. Danfoss has a factory in Haiyan, and therefore the local government in Haiyan has the interests in initiating more collaboration with Sønderborg. With this initiation, a coordinator, e.g. an organization, which understands cultures and systems in both countries and could ensure things happen, is significantly important.

Although many Danish SMEs have interests in business opportunities in China, there are several challenges to overcome, e.g. political uncertainty, culture barriers, intellectual property rights (IPR) issues and lack of resources. A common approach for SMEs to enter the Chinese market is over the collaboration with local distributors, but the success relies on the capability of the distributors. And the SME has very limited control to the market. Another approach is to create a joint venture with a Chinese company.

The way ahead is, based on experience from the research, that Danish SMEs should join as a cluster and be present in China as a strong group. By sharing resources and risks, it makes the business in China possible. In addition, with the extra support from the Chinese local government, Haiyan in this case, has built a Danish Industrial Park that welcomes Danish SMEs to setup their offices and manufacturing facilities.

Based on the research findings the practical implications and recommendations to SMEs are:

- Have a customer in mind while starting a collaborative project
- Mind differences in business models of various project stakeholders
- Financial incentives can help to initiate collaboration, but do not guarantee the success
- Do not get fully dependent on external funding (do not let it to crowd out your intrinsic motivation and curiosity)
- Good facilitation/communication/ joined goal setting and awareness of each other's expectations could significantly increase the commitment among partners
- Be open and ready to exchange ideas with good sparring partners and be open for feedback (positive knowledge spillover)
- Engage with research institutions, GO & NGO in the early phase of ideation. Use their formal and informal network to get new partners on board.

PRACTICAL SMART FACTORY CASES

This chapter will document practical examples for realization of the research findings.

AutoSyd - Automation in Southern Denmark

To test and validate the Smart Factory ideas, we decided to launch a project that was named AutoSyd – Automation in the region of Southern Denmark. The purpose of this project was to formalize a consortium of companies with complementary competences with the task of analyzing the potential for automation in SMEs, and come up with strategies and plans for SMEs in the region. The consortium was formed with the University SDU as the orchestrator and facilitator, Pehama and Hannemann Engineering in mechanical designs and Alsmatik and Automatic Syd within electronics and automation control. EUC Syd took part to ensure the vocational training and hosting a training facility. URS –"Udviklings Råd Sønderjylland" was the first facilitator, this was later taken over by SDU. The consortium was in other words designed to complement the competences within mechatronics from theory to practice.

The project needed seed founding and an application to Syddansk Vækstforum and EU's regional funds was made, and the project was partly funded. During this collaborative work more than 100 companies have been contacted, out of which more than 30 companies have been visited for interviews, analyzed and 14 strategies have been developed for how to improve SMEs to make them "smarter".

The project included a documented collaboration agreement. A steering committee was appointed including representatives from the major stakeholders. In the daily operations, when visiting companies and developing solutions, there were always more partners involved to ensure that all the competences came into play and in that way, the project team was able to generate innovative solutions. The AutoSyd collaboration model is illustrated in Figure 7.

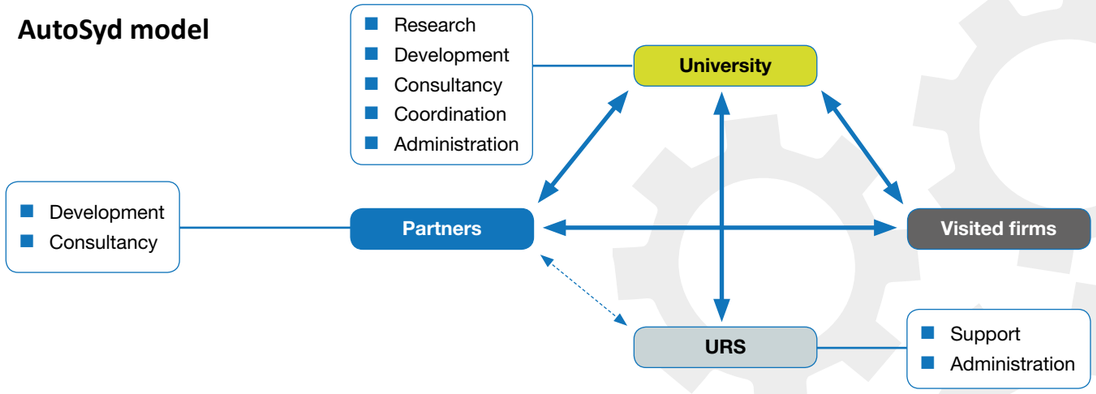


Figure 7. The AutoSyd collaboration model

The aim was through collaboration to bring knowledge and actual solutions concerning automation and technology into the SMEs. We have applied an action research approach, which means that we both want to solve problems in the SMEs and create knowledge and contribute to science in a broader sense.

Investigating the SMEs, general issues recur. SMEs are individually within specific business segment with a specialized production. Most SMEs in this research did not have a strategy for their production and investments. Machines and equipment is fitted in the production, where space is available, without long term planning. The stock and flow of material was unnecessary complex, with high work in progress - WIP, long lead times and many "dead" components in production. The planning and control (order, material) is often done manually without proper tools and procedures, which makes it hard to prioritize tasks and to keep an overview.

Based on the experience throughout the project we conclude:

- Most SMEs are challenged with a high mix and low volume production – HMLV, which sets new demands to automation technology.
- SMEs have to work strategically with production that makes more long-term planning possible and consistent.
- The planning and control systems have to be simpler solutions to support personnel at the shop floor.
- Attention has to be on working with lean tools to reduce waste and create flow to prepare for automation.
- SMEs have to think in simple Lean Automation solutions.

The research and collaboration in the consortium between the university and the four automation providers, has resulted in two generic concepts or products for automation solutions to SMEs in line with the approach of Lean Automation to help in the direction of HMLV production. The simple Lean Automation solutions are flexible and can be reconfigured, when conditions are changing.

Product 1 – The Production Feeder

Most SMEs have CNC machines (milling, turning etc.) with manual material handling. In this concept, a flexible feeder system has been developed to feed CNC machines automatically, see Figure 8.

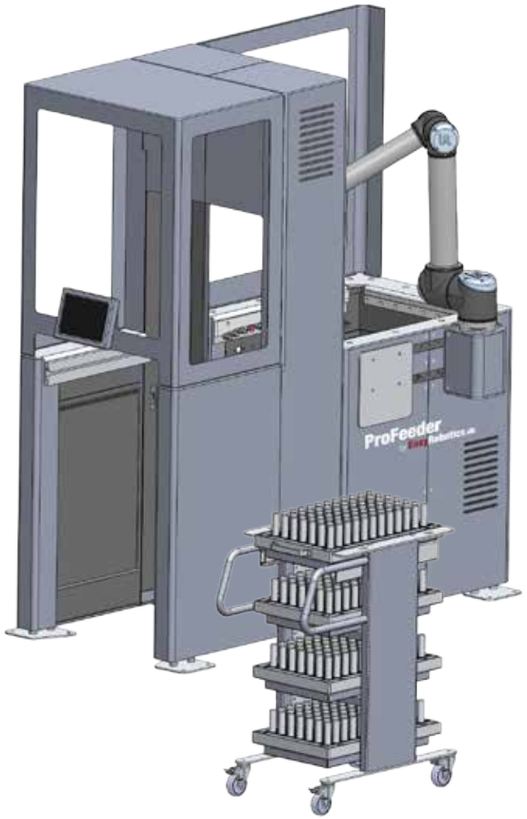


Figure 8: Flexible CNC feeder, robot (a) and magazine (b)

The innovative element in this solution lies in the feeder that is flexible and adaptable to any type of robot and flexible to new products. The feeder has a flexible magazine that by a human can be filled/emptied with products (while CNC-robot is working), the robot and CNC machine can then work for several hours without interference of a human. The feeder is based on flexible modules, i.e. it can be rebuilt and reconfigured to new tasks. The feeder is mounted on wheels, so that it can move between machines. In this way the CNC machine can also be operated manually if required. This concept increases flexibility and Overall Equipment Efficiency, OEE.

Product 2 – The Flexible Assembly cell

Most manufacturing SMEs have assembly tasks and demand more flexible assembly, that are easy to change and setup for new products. This product is built of flexible modules that through different configurations can be operated by the operators themselves, see Figure 9.

The concept can be configured for different level of automation, where assembly and handling may be by any combination of humans and/or robots in collaboration. The robots will in the final setup be moveable and operate as helping devices for simpler work tasks, where the humans handle the more flexible and complicated tasks. The assembly cell concept provides a high degree of flexibility and scalability, combining the best characteristic from both automation and human operators.

The two examples of products/concepts described above are solutions/products coming out of collaboration, where most likely none of these solutions would have been developed without the complementary competences. There were also three other solutions that most likely will be turned into products in the near future, the one as a simple planning system based on cloud technology and internet communication directed at internet of things, IOT.

The engineering company COWI was to evaluate the project and they concluded: *"The strength in the project has been the collaboration between the university and the private system providers of automation solutions and the concepts reach out of what a single partner would have been able to develop. The companies experience that the products and the concepts coming out of the project is based at solid theoretical analyses of the SMEs involved and at the same time creating sustainable solutions by the SMEs"*.

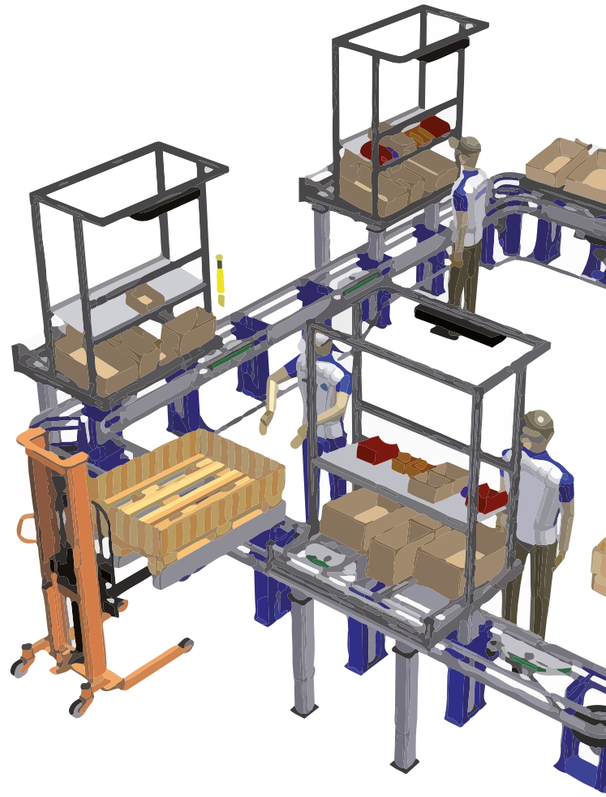


Figure 9: Flexible and module-based assembly concept

Green Water and Power Electronics Test lab

SMAF has been researching a number of other cases and has been inspired by a couple of other projects:

GWRP – Green Water Research project

The purpose of GWRP is using sea water for cooling and heating houses. It started as a test installation at Alsion in Sønderborg as a student project. The next step is a higher proof of concept installation in the so-called Hardeshøj building down to Alssund. The consortium has been the University, Danfoss and a number of SMEs. Sponsors have been Sønderborg Municipality and Danfoss.

Power Electronics Test – Green PET laboratory

The main purpose of the Green PET Lab is to support Danish firms in the development of energy efficient products by offering the firms access to world class mechatronics testing facilities combined with technological service and advice. The Green PET Lab will work as a cradle for new testing methods and set new standards for advanced testing of energy efficient products, which can contribute to fulfilling the government's energy policy objectives. The Green PET Lab facilities will continuously be developed further in close collaboration with universities and the participating firms, and will contribute significantly to creating an international research and education environment within power electronics.

CLEAN, DELTA and SDU have been involved in setting up the Green PET LAB facilities, where partners are from the mechatronics companies Servodan, Lodam, OJ Electronics, Banke Accessory Drives, Linak, Danfoss, Siemens, etc.

THE SMART METAL FACTORY

Smart Metal Factory has the purpose to develop an actual Smart Factory, and try out the theories in practice. In order to do so a more detailed analysis of the industrial landscape in the region of Sønderborg was conducted. The result pointed to the fact that there is a clear overrepresentation of metal processing companies and that the number is growing to about 360 businesses according to Sønderborg Vækstråd.

Through interviews with 22 metal processing companies it became clear that there might be a big interest for collaboration about a Smart Metal Factory. The companies responded very positively to the idea of having a facility that can manage sheet metal fabrication, welding in particular. In many cases, if welding is a part of the product, the companies simply outsource the entire chain of processes. The majority of outsourcing has been made to low cost countries such as Poland. However, in Poland the wages has quadrupled in the last 15 -20 years *(Source Tradingeconomics.com)*, yielding fewer saving when outsourcing. At the same time automation and especially robotics have been subjected to a decrease in price and a rise in flexibility, this is reflected in the fact that 39 % more robots were sold in the metal industry in 2015 compared to 2014, while the overall robot sales rose only 16 % (Source International Federation of Robotics). These two conditions may enable profitable automated welding in Denmark.

When asking whether the companies would take the role of customer, partner, investor or facilitator, the reactions were clear. If Smart Metal can manage a price near Eastern Europe standards and maintain the quality, all companies would prefer sourcing closer to their own manufacturing site and thereby become customers of the Smart Metal Factory. Most of the companies did not see themselves as investors, but they would be willing to be involved as partners and collaborators. A few considered becoming the facilitator of the Smart Metal Factory.

The companies stated that in order to create a profitable Smart Metal Factory in Denmark, the entire value chain should be considered, because one single point of contact alongside the prize are the dominant reasons for ordering parts in for example Eastern Europe. In order to accommodate the statements from the companies, the Smart Metal Factory project concluded that the solution will have to be split into two:

- A Smart dedicated welding factory with the basic sheet metal processing capabilities
- Establishment of a network of partners with complementary process equipment to be able to master the entire value chain.

The Smart Dedicated Metal Factory and the technologies

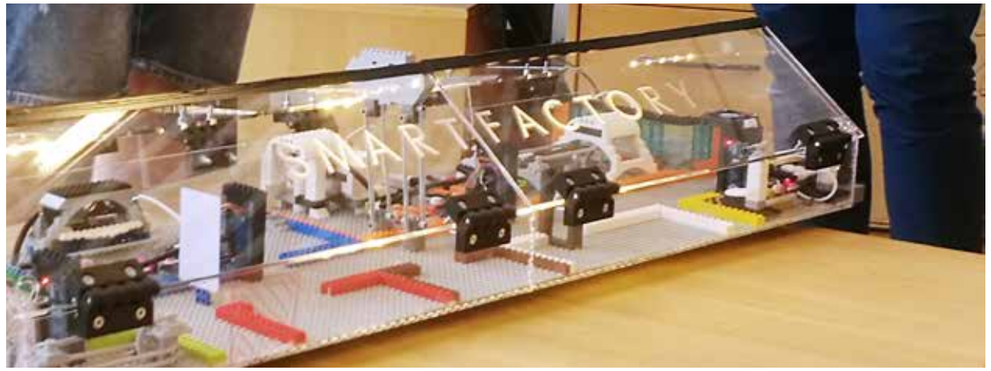
The focus is primarily sheet metal manufacturing. The challenge in the dedicated factory is not the complementary processes, such as cutting, bending, deburring and assembly. The challenge will be the flexible welding process, but in these years a lot of different solutions for flexible welding are flourishing, from both universities and robot integrators. The Smart Metal Factory project has obtained tenders from two integrators, one which is a spinoff of from a university project and another from one of the largest welding robot integrators on the Danish market and both - or in combination - seem very promising.

The solutions are spanning from two collaborative robots to a full scale Flexible Manufacturing System (FMS) for welding larger items. The solution is not fully automated, as it relies on manual labor to fixate the items that needs to be joined. The FMS solution consists of a robot, a manipulator and a sophisticated seem tracking system. All machine programming is planned to be offline programming directly based on 3D CAD models. If not investing in the equipment there is also the possibility for making use of leasing agreements, this might become of use in the startup process of the Smart Metal Factory.

The location of the Smart Dedicated Metal Factory is as for now set to an empty warehouse facility in Rødekro, this choice is based on access to the highway and distance to customers.

The Smart Metal Factory Resource Sharing

During the interviews the attendants where asked, whether they know Uber and AirBnB, which are the largest Taxi and Hotel company in the world respectively and this is so without owning neither taxis nor hotels. Secondly, they were asked, if they could imagine the largest metal processing company in the world, not owning one single metal processing machine. This opened up for a discussion about sharing machines and capacity. Most of the companies were reluctant towards sharing their actual capacity utilization, but they were willing to share a certain percentage of their capacity through a resource sharing platform. All of the companies agreed to that an online platform, single point of contact and design for manufacturing competencies, would be beneficial for them.



The combination of the Smart dedicated Metal Factory and Resource sharing

The resource sharing cannot stand on its own, on the other hand it will be more or less impossible to have all processes in house, especially when it comes to surface treatment, there are literally thousands of different surface treatment processes. However, resource sharing in unison with the Dedicated Smart Metal Factory is thought to become an interesting solution both for the factory itself, but more importantly for all the metal processing companies in the region.

The graphical interpretation, in Figure 10, of the Smart Metal Factory illustrates how the relationship between suppliers, customers, partners etc. is proposed to be. This indicates that there is a need for a facilitator, who can be the single point of contact, for all the partners. This single point of contact is expected to be a person in the Dedicated Smart Metal Factory.

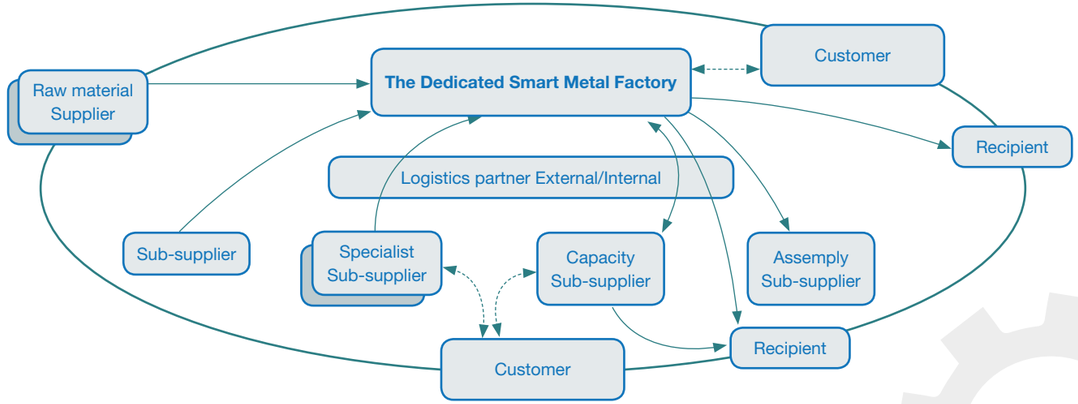


Figure 10: Dedicated factory and Resource sharing combined

Business prospects

There are plenty of automated welding sites for high volume manufacturing in the Region of Southern Denmark, but there is no such thing as a flexible welding factory as described in the Smart Metal Factory. From adding up all the tenders, plus the estimated cost of peripheral equipment, the overall cost price for the basic setup is roughly estimated around 22 million DKK. Further the annual running costs are estimated to 3.2 million DKK based on employment cost, energy consumption and facility running costs.

The industry in the area of Sønderborg estimates that they annually outsource metal processing for more than 200 million DKK. This along with the positive statement on SMEs willingness to back shoring, if the Smart Metal Factory can deliver as promised, makes it a potential business case. If the Smart Metal Factory can reach a market share of only a few percentages from the outsourced metal processing, then there will be basis for a sustainable business, with a sufficient starting turnover.

SMART FACTORY LABORATORY AS PART OF THE INNOVATION LAB

The Smart Factory lab is a cornerstone in the newly established Innovation lab at the Mads Clausen Institute at Alsion in Sønderborg, supported from Bitten and Mads Clausen foundation. The Innovation Lab is a physical environment corresponding to the stages of the innovation process. This allows participants from companies and students to move from a theoretical approach to practical and applied innovation principles. The Innovation lab is dynamic and may change according to the innovation challenges and changing conditions. The physical outline of the lab is represented in Figure 11. The lab is a 150 m2 room and is split up into four sections, corresponding to the stages of the innovation process: creativity, design/prototyping, production/operations, and marketing/business.

In all of the sections, expert knowledge can be brought in. The lab itself holds different enablers and technologies, that can foster the specific processes in each section. The different sections are briefly described below.

Creativity. The creativity section is designed to actively pursue ideation. Writable surfaces and a comfortable environment allow participants to explore, rethink, and discuss ideas, disregarding the problem background. The ideation success depends on an experienced facilitator or adequate creativity experience of the participants.

Design/Prototyping. This stage contains tools to pursue active prototyping. Besides access to 3D modelling software, there are material samples to build prototype mock-ups that enhance ideas through tangibility. A material library allows handling of different substances. In the end, this stage significantly increases both the idea and the feasibility, which should be a prerequisite to consider operations and design aspects.

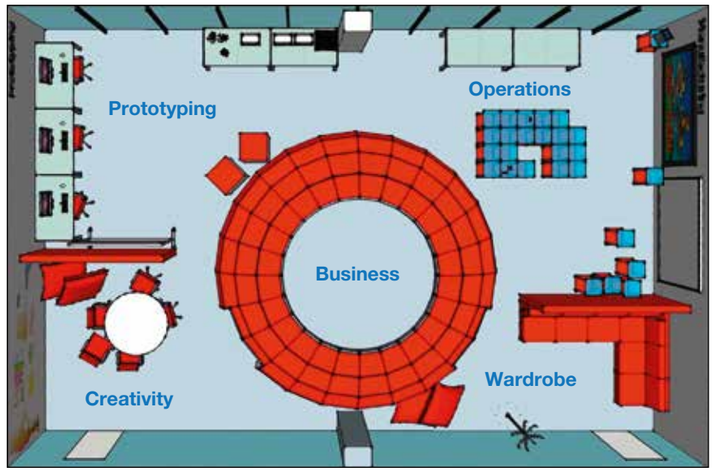


Figure 11: The innovation lab seen from above

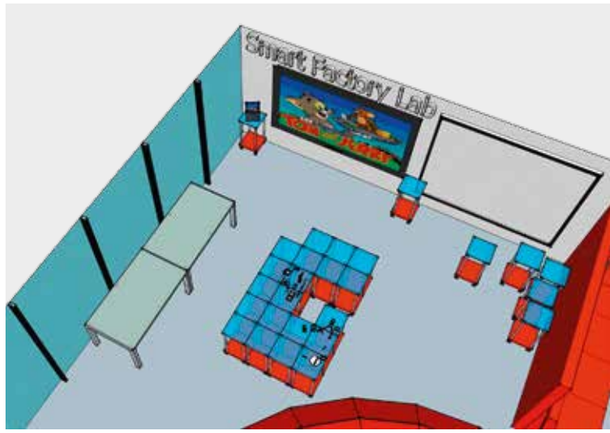


Figure 12: The Smart Factory Lab (operations/manufacturing)

Operations/Manufacturing (SMART FACTORY LAB)
The operations is where we have developed the Smart Factory Lab, where innovative experiments may be performed. The core output is to take whatever product or service, that has been developed in the Prototyping section and take it through the manufacturing innovation phase to realization. The setup is centered around the reconfigurable environment, which are designed for seamless integration and reconfiguring, based on moveable workstations for mapping and working innovatively with materials, processes and supply chain.

Most companies and innovation tasks will be different and have different innovation challenges, but in a typical session in the Smart Factory Lab, may contain activities related to material, manufacturing processes, production, material handling/transport, supply chain and final product/service cost price calculations.

The Smart Factory lab is targeting the companies in the region, especially the SMEs that may come here and collaborate on innovation. In order to help a broad target group, the lab have to be very flexible. The innovation capabilities lays within the production technology, automation, lean tools and digitalization. This is in line with the theory behind Lean Automation, where the purpose is to make simple and inexpensive automation solutions targeted at SMEs.

A major purpose with the Smart Factory lab is to get SMEs and technology/automation providers to think more module based and reconfigurable in the future solutions.
The Innovation lab in general and the Smart Factory lab in particular are expected to be an active innovation environment, where SMEs from the region will be able to collaborate on new innovative solutions.

Over the last years, we have seen several collaborations with companies regarding mechatronic product development. In collaboration with PolyPower, we were discovering the new applications of their state of the art sensors. Going through the innovation process, from ideation to manufacturing, we developed several projects including the business concepts with working prototypes. Based on the support from the Smart Factory concept, we can get an overview on the whole process with multi-stakeholder involvement, which boosts the new product development process in these projects. Reversely, knowledge from these projects also contributed to the Smart Factory concept.

CONCLUSION AND PERSPECTIVES

The Smart Factory project SMAF has taken the involved project partners into many interesting and challenging areas. It has been a challenge to get the SMEs in the mechatronic cluster fully involved and taking the risk to launch innovative SMAF solutions, because the SMEs have been focused on their core existing businesses. The Smart Factory has nevertheless been the seed to foster a number of new initiatives, and SMAF has been an umbrella for the research and development within the very interesting topic of the SMART FACTORY that now many researchers and companies are referring to. The project has researched the ecosystem in the region of Southern Denmark and made some interesting observations to develop a better understanding of mechanisms within SMAF. Last, but not least, within the scope of the project we have documented the collaboration ingredients and propose a set of recommendations both for the industry and policy makers.

We have launched the AutoSyd project, where the collaboration among university and the companies has generated results that none of the companies could have fostered themselves. Because of the SMAF collaboration, a number of lean automation concepts or products have been initiated.

As a practical case for SMAF, the Smart Metal Factory was identified, where the technical foundation and business model has been discussed and a total new model for a Smart Factory has been presented. This model may be a sustainable local supplier of metal component, and thereby bring a bit of production back to Denmark and the region of Southern Denmark. SMAF has fostered new ideas and the next research project called Smart Metal will run from January 2017 in 9 months to research more in detail the technology as well as the organization and financial model for the Smart Metal Factory further.

As a result of SMAF, a Smart Factory laboratory has been launched as part of the newly established Innovation lab at SDU Sønderborg. The entire idea of the Innovation lab is collaboration with SMEs as well as engineering students to work on technology entrepreneurship. The Smart Factory lab focus at the operations or manufacturing part, where new innovative lean automation solutions can be developed that are super flexible and reconfigurable to handle high mix low volume - HMLV production.

The Smart Factory project has initiated research at both Danfoss and Linak within the scope of digitalization and Industry 4.0 to research the Smart Factory. The plan is to continue the research through a couple of new PhD projects and engineering master students.

The Smart Factory projects and research will be presented at the VTM 2017 “Værktøjsmaskiner 2017” from 28th of February to the 3rd of March 2017, which is a major fair to the Danish industry focusing on metal manufacturing. SDU – University of Southern Denmark - will together with AAU – Aalborg University - and some of the SMAF SME partners establish an exhibition area promoting the Smart Factory project and the activities and research to come.

The research from the Smart Factory project will during the summer of 2017 be finally documented in the PhD thesis by Agnieszka Radziwon with the title “Exploring inter-organizational collaboration for innovation in a regional ecosystem.”

During the project a number of papers and documents have been published, that are available at the Smart Factory webpage: www.sdu.dk/smaf

Please have fun in further reading and good luck with collaboration and new technology!

“Ingen kan alt
Alle kan noget
Sammen kan vi endnu mere”

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