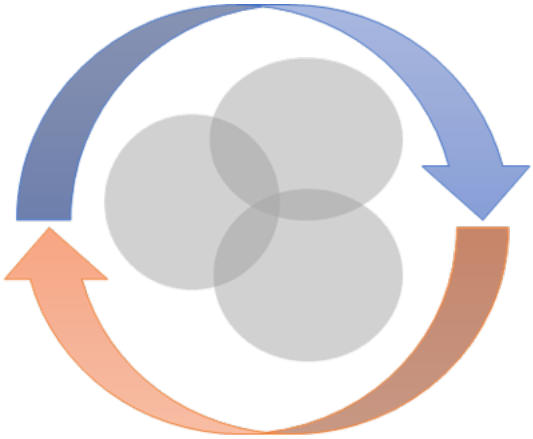
GIMLE -

Digitalized collaboration for competitive and sustainable product realization

Public report



GIMLE

Modelbased collaboration with feedback

Project within Hållbar produktion

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1. Summary

The availability of digitized data, knowledge and models enables a paradigm shift towards new business models based on shared information and model-based collaboration. Instead of building on traditional ways of working, the vision is to create digitalized methods based on cross-disciplinary collaboration and availability of common sources of information. Methods include efficient use and combinations of digital models in digital threads, and the creation of new knowledge, based on human experience and the application of AI to large amounts of data. This project addresses this vision in the domain of industrialization within the vehicle industry. Model-based industrialization means using digital models and simulations in an interconnected way to analyze production aspects and to modify the product and production system. Although there exist islands of implementations for this in vendor specific systems, there is a lack of generic methods for creating, using and communicating information, knowledge and models between various stakeholders and activities throughout the business processes. The Gimle pre-study had the goal of making a basis for developing a reference model for model-based industrialization. Based on the status, needs and experience within the partner companies, identified white spots and state-of-the-art, the pre-study provided a basis for planning a full-scale project with an expanded network of partners. The long-term goal is a generic reference model for industrialization that supports efficient use and combinations of information and the design of information architectures in various companies with different conditions, products, networks of stakeholders and vendor systems.

Project focus: Industrialization (the process of making the product possible to manufacture in large scale), with the goal of lower product cost and faster progress from design to manufacturing.
Project concern: Closing the gap between design and production; exploring model based engineering and the use of models and digitized knowledge in the process of industrialization, where a combination of models, simulations and experience (human and AI-analysis) is used.
Main deliverables: 1) Current state, gaps and method in participating companies. 2) Basis for a generic reference model that supports the design of model-based industrialization in various contexts. 3) Plan for implementation of a use case of model-based industrialization, to be demonstrated in the PMH testbed. 4) Basis for feasibility for full project.

The Gimle pre-study is now the basis for a full project, focusing on model based collaboration and digital threads. Similarities and differences in information management of process planning the assembly versus part manufacturing were identified, going from requirements to instructions to production and back. This result will serve as a foundation to be explored in a full project, with the planned result of practical implementations as well as general principles for model based development.

2. Sammanfattning på svenska

Gimle var en förstudie med huvudmålet att skapa ett projekt som utforskar och utökar användningen av digitaliserade modeller och kunskap i produktframtagning. Affärsmålen är att bidra till hållbar konkurrenskraft genom en närmare interaktion och delning av digitala modeller och erfarenheter mellan intressenter inom FoU och produktionsavdelningarna.

Några delmål:
• Utöka den information som kan representeras i digitala modeller och sedan användas i samarbete och kommunikation mellan grupper med olika perspektiv.
• Metoder för att använda feedback och erfarenheter från produktion för att stödja industrialiseringsbeslut, baserat på identifierade behov.
• Metoder för att skapa digitaliserad kunskap baserad på feedback från många källor och situationer, användbara för att fatta beslut baserat på bredare erfarenheter.
• Generiska modeller och strategier för modellbaserad industrialisering, användbara för olika produkter, produktionssystem och bredare intressentnätverk som involverar kunder och leverantörer. Detta innefattar standardisering av information som kommuniceras samt harmoniserade sätt att arbeta.

Förstudien Gimle är nu grunden för planering av ett fullskaligt projekt med fokus på modellbaserat samarbete och digitala trådar. I förstudien identifierades likheter och skillnader i informationshantering inom planering av processer för montering kontra komponenttillverkning, från krav till instruktioner till produktion och tillbaka. Detta resultat är tänkt att utforskas i ett fullskaligt projekt, med målet att ta fram både praktiska implementeringar och generella principer för modellbaserad utveckling.

3. Background

The availability of digitized data, knowledge and models enables a paradigm shift towards new business models based on shared information and model-based collaboration. Instead of building on traditional ways of working, the vision is to create digitalized methods based on cross-disciplinary collaboration and availability of common sources of information. This includes efficient use and combinations of digital models in digital threads, and the creation of new knowledge, based on human experience and the application of AI to large amounts of data. This project addresses this vision in the domain of industrialization within the vehicle industry. Industrialization involves analyzing production aspects such as machinability, assembly or flow of material, and modifying the product and production system for better production. Model-based industrialization means using digital models and simulations in an interconnected way to support this process with higher efficiency. Although there exist islands of implementations for some products in vendor specific systems, there is a lack of a generic

reference model, which describes shared concepts, flow of information, its qualities and integration, as well as methods for using the various models throughout the business processes. Such reference model would support the design of IT system architectures for new products and for industrialization in a network of stakeholders using different vendor systems.

4. Purpose, research questions and method

This pre-study has the goal of making a basis for developing a reference model for model-based industrialization. Based on the status, needs and experience within the partner companies, identified white spots and state-of-the-art, the pre-study provided a basis for planning a full project with an expanded network of partners. The long-term goal is a generic reference model for industrialization that supports efficient use and combinations of information and the design of information architectures in various companies with different conditions.

Research questions included: How to support the communication of constraints and possibilities of production in the development of new products? How does the information flow look like and what information could be included in models to support the development process?

Apart from project coordination, the project was divided into 5 work packages:

- WP1. **State of the art** – Identification of challenges, gaps and opportunities for realizing digitalized industrialization.
- WP2. **Study of industrialization work process -** Prestudy of the interaction between the design and production departments in an automotive company, with identification of the work processes, involved roles, models used, interfaces and information flows and requirements between internal stakeholders. Identification of needs for and benefits of feedback from production and operations (e.g. generated through applying business intelligence to production results or experience from services) in the industrialization process.
- WP3. **Use case demonstrator -** Draft of demonstrator of using well-structured and context-based feedback from production to support model based industrialization of a component of Scania's demonstrator product in the Smart factory lab: the sprocket hub of a pedal car.
- WP4. **Create initial reference model -** Compile the initial reference model based on input from WP1, 2 and 3. Draft of model of the interfaces and information flow between stakeholders in product design and production. Detail a generic industrial use case for closing the gap between design and production by applying model-based engineering.
- WP5. **Document gaps and plan for remedy -** Documentation of gaps and development of full project proposal.

A collaboration between the R&D and Production&Logistics departments at Scania was initiated. Industrial partners provided experiences, existing models, and current ways of

working in a series of workshops. Workshops circled around existing workflows from design through industrialization on a higher level as well as around more detailed model based process planning of components at Scania. Together we established a research group for a larger project, identifying gaps and challenges, and an initial plan for how to go forward to define a framework for model based industrialization.

5. Objective

Objectives of the pre-study was to investigate needs and current solutions in order to make a basis for developing a full project focusing on model-based industrialization.

The initial objective was to contribute to research and development of generic principles: A reference model that provides insight into the aspects of elements to consider when developing new elements for digitalized collaboration – generic and reusable for different value networks.

- Business reference model – for example: stakeholders in value networks; key issues, values and risks; workflows and decisions.
- Technology reference model – for example: ICT reference architecture; related applications and services; functionality and interfaces of applications.
- Information reference model – for example: semantics and ontology (both domain and upper); knowledge modelling; types of data, models, and experience used; methods for creating information from measured data (AI); information flow and principles for combining models.
- Principles for interrelating the business- technology- and information reference models.

The objectives were refined and slightly changed during the project towards defining generic principles based on our selected use cases. The aspects of the reference model concerned characterizing and relating production planning scenarios based on type of product (part or assembly); life cycle stage (conceptual design; detailed design; process planning; production); disciplines/stakeholders (internal departments; supplier organizations) and types of information and models.

6. Results and deliverables

Deliverables in line with the 5 work packages presented in section 4:

D1. Structured documentation of state-of-the-art: Existing material (methods, IT-applications etc.) and state-of-the-art in previous projects were collect and saved into the common file directory Box. Most influential were the results from the FFI MPQP project, the PMH project “Vertical&Horizontal” and the Production2030 testbed projects DigIn and PMH Application lab Smart sensing framework.

D2. **T**he interaction between the design and production departments at Scania were studied, with identification of the work processes, involved roles, models used, interfaces,

information flows and requirements between internal stakeholders. Identification of type of feedback needed from production and operations in early product design.

D3. A demonstrator of process planning with feedback based on information model standards and a collaboration within WG 15 was presented and served to understand needs and challenges in model based process planning in relation to a concrete example.

D4. Draft of reference model for model-based ecosystem for industrialization as described above, based on the state-of-the-art, company specific studies and demonstrator development.

D5. Organization and proposal of full project.

During the pre-study, the work in WP2 was developed in several stages:

1. A potential case study was identified, focused on the interactions between product design, external suppliers, and production.
   The case study focused on the assembly domain and involved the design of a component for the cabin together with the external supplier. Several points of interest emerged from the historical registers of this product that made them attractive to analyse. One of the highlights of this case study was the **interaction between the company and an external supplier in the joined effort to design and improve the component**, which ended up in a design that was a compromised between the targets and the feasible design. The scope of the case study was presented to the participants during the first meeting to give them an outlook of the WP2.
2. With the case study as a trigger, several discussions were held during the joint workshops with all participants, to identify the points of interest for further analysis.
   The feedback received during those workshops were used to identify the dimensions in which the pre-study should emphasize. It was clear from this point that the communication and information sharing mechanisms are the important pillars during product development and therefore should be deeply analysed.
3. Information related to the case study was gathered and analyzed during internal meetings with the WP2 working group.
   There were some efforts to gather information about the case study, but due to the long time that passed since its design, it was not possible to access all the documentation, which was an important hurdle in the work of the WP2. Nevertheless, some files containing historical information, and final engineering drawings, were used to conduct the analysis and internal discussions. During these meetings, the participants of the WP2 raised attention to certain points of the product development process, some of which were not possible to figure out based on the information available, which is why it was defined to conduct interviews to clarify these points.
4. Specific questions that emerged from the precedent analysis were integrated into an interview guide. Two interviews were conducted involving people working in the company in the roles of interest: design and production.
   Based on the dimensions identified in the workshops and the points of interest defined throughout the internal meetings, the interviews were conducted trying to answer all of the questions raised. It is important to mention that it was difficult to find the specific engineers involved in the development of the case study, due to the time passed. The company's product development (PD) process was understood in its current state and not for the actual PD process followed during the development of the studied component; it was not possible to define the deviations from the company's PD process for this particular component.

The interviews and their transcriptions were analysed to answer most of the questions related to the case study**. A more solid view of the internal PD process was created** by establishing similarities between the development with external and internal suppliers. After the execution of the pre-study, the following results were obtained:

- The company's product development process was understood. It was possible to identify the **different stages, the existing communication flows, and decision points in this process**. The interviews helped in recognizing the similarities between the PD process with **internal as well as with external suppliers**. However, it was not possible to find sufficient information to confirm that the studied component was developed under the same process at that time, due to a long time since its development.
- Understanding the roles and communication of the main departments, it was possible to identify the current paths for receiving feedback from different stages in the PD process.
- It was possible to identify the roles of the R&D and production departments and workgroups in the company's PD process, though, it is necessary to conduct more interviews to understand the role of support departments, e.g. purchasing, legal, styling, and their influence to the PD process.
- The software tools and filetypes utilised to support the PD process were identified. The current practices in documenting, storing and sharing product information with internal and external stakeholders were distinguished, as well as the execution of the handover of a project when it is needed (due to personnel change, for instance). It was suggested that although current practices work, there is room for improvement and optimization in the management of information.

The full project will contribute to the FFI Sustainable production sub-programme SMART for sustainable competitiveness with reduced cost, sustainable development and shorter time to production through:

- Closer interaction and sharing of models and experiences between stakeholders in the R&D and production departments.
- Ability to simulate production aspects and iterate solutions already during early product design (model-based collaboration in the internal value chain).
- Methods for creating and using digital knowledge with ability to use feedback and experiences from production to support industrialization decisions.
- Strategies for model-based and collaborative industrialization, usable for various products, production systems, and wider stakeholder networks (involving customers and suppliers).

The project will contribute to the *overarching FFI objectives of*

- *increasing the Swedish capacity for research and innovation,* through generic methods for cross- disciplinary and model based collaboration between stakeholders in R&D and production.
- *developing internationally interconnected and competitive research and innovation environments in Sweden* through a collaborative development of a use case within the standardization working group ISO TC 184/SC 4/WG 15 Digital manufacturing.
- a general aim of the open ecosystem approach is to involve all relevant stakeholders, such as *small and medium-sized companies, the participation of subcontractors and cross-industrial cooperation* in a common ecosystem enabled by a reference model of the functions, interfaces, values and roles of such ecosystem.

- *promoting cooperation between industry, universities and higher education institutions,* through a close collaboration between researchers at KTH and strong stakeholders in automotive industry (Scania, Sandvik Coromant).

7. Dissemination and publications

7.1 Dissemination

The expected results will be utilized as a basis for a full study.

How are the project results planned to be used and disseminated?	Mark with X	Comment
Increase knowledge in the field	X	Basis for full study. Medium term (knowledge-building project, possible introduction 5-8 years after completion of project)
Be passed on to other advanced technological development projects	X	Basis for implementations in model based design within the partner companies.
Be passed on to product development projects		
Introduced on the market		
Used in investigations / regulatory / licensing / political decisions		

7.2 Publications

A research paper around industrialization and representation of part assemblies as described in section 6 was written in a collaboration between the Scania and KTH PhD students. TBA

8. Conclusions and future research

The conclusion is that there is a big interest in industry to work in a more model based way and to make use of the results from production.
Digital twins and digital threads are buzzwords that represent a real interest to make the information flow from requirements to production and back both more lean and available to the decisions along the lifecycle. Model based engineering is broadening from being an interest of technicians, to an interest of the managers of work processes.

Thus, there is a genuine interest in understanding the information flows – the “digital thread” and in how to digitize more requirements and properties into the 3D-models. Our discussions with the industrial partners also showed that there are many similarities for managing information in assembly and part planning which could serve as a basis for general principles for adapting information management to different domains.

So, the interest in managing and modeling information is grounded. Although there are many issues to resolve concerning the representation of information, there is a specific need to understand the principles for collaboration and how models can be used to serve collaboration.

“Collaboration is the process of two or more people, entities or organizations working together to complete a task or achieve a goal.”
In GIMLE the purpose of collaboration is to **develop** a solution (an automotive product or process), considering various constraints – it is a design activity, which involves trade-offs, open issues, alternative solutions, and decisions (negotiations).

A next step is a deeper study of how models can be used to support this activity in process planning – with a collaboration between disciplines of product design and process planning (for part manufacturing and assembly). This includes the feedback loop and the ability to use experience gained when realizing the solution – in our case the results of production – for the next round of development (either improvement or new design).
A next step is also to define an information context, which can show key properties/parts for each discipline as well as the interdependencies between these different parts. This context should serve to create understanding, discussing trade-offs, testing solutions, interrelating the overall properties to more detailed models/analysis required within each discipline. We call it a Collaboration context model. Through this model the partners can share a common and dynamic context that interrelates various perspectives of the object being developed. It is easy to update with current information from different sources. Collaboration based on this common, “live” model encourages development and decreases misunderstanding.

9. Participating parties and contact persons

Scania: one of the world's leading manufacturers of trucks and buses for heavy transport applications, as well as industrial and marine engines. The company operates in about 100 countries. Scania's research and development and European component production is concentrated in Sweden. Mariam Nafisi; Mariam.Nafisi@scania.com

Sandvik Coromant: the world's leading supplier of tools and know-how to the metalworking industry with products, solutions and innovations that improve processes, ways of thinking and drive industry standards. "We believe model-based information is a key for unlocking future opportunities as collaboration with our customers and suppliers takes new shape in a digitized world." Bengt Olsson; Bengt.Olsson@sandvik.com

KTH PMH: The Powertrain Manufacturing for Heavy Vehicles Application Lab (PMH Application Lab) is a research center at KTH, which is operated in collaboration with the German research organization Fraunhofer. PMH Application Lab works for the improvement of technologies in the field of powertrain manufacturing for heavy vehicles to strengthen the competence of the Swedish industry in this area. Darya Botkina; dbotkina@kth.se

KTH IIP: branch at KTH with focus on research and education concerning all aspects that support and enable production. The Digital Smart Production (DSP) unit at IIP conducts research and education in the domain of digitalization and integration of information and IT technologies in the manufacturing domain. Gunilla Sivard; gunilla@kth.se