COMPLEX
Support for Operation and Man-hour Planning in Complex Production

Komplex produktion: Stöd för optimering av direkt och indirekt arbete, kompetens och information

Application for funding from Vinnova's call "Hållbara produktionsstrategier" (Sustainable Production Strategies) within the programme "Produktionsstrategier och modeller för produktframtagning" (Production Strategies and Models for Product Realization).

Notera: *Projektet är ett av två projekt som avses drivas parallellt, med samma huvudproblem och målsättning men med olika fokus. För det andra projektet söks finansiering från Flander's Drive i Belgien (ansökan 14 december). Eftersom det är viktigt med samförstånd och kontinuerlig samordning mellan dessa två ansökningar och projekt, skrivs båda projektansökningarna på engelska. Margareta Groth har beslutat att detta går bra (telefon & e-mail 8 sept).*

Sammanfattning

Framtida produktion förväntas lokaliseras till de fabriker som flexibelt och effektivt kan producera nya produkter som uppfyller hållbarhets- och miljökrav. Förändrade krav och lösningar, som t ex elmotorer och hybrider i personbilar, påverkar hela produktionssystemet och ökar drastiskt komplexiteten. Projektet tar fram ny generell kunskap för att strategiskt planera, hantera och optimera komplexa produktionssystem. Begreppet komplexitet analyseras och modelleras, och en metod tas fram för att kunna mäta, jämföra och kommunicera graden av komplexitet, från stations- till fabriksnivå. Här ingår analys av komplexitetens inverkan på relationen mellan det direkta och indirekta arbetet i produktionen, informations- och kompetensbehov, och metoder för att stödja detta. Projektet genomförs av seniora forskare från Swerea IVF (ledning) och Chalmers, i nära samverkan med Volvo Cars, Parker Hannifin, Stoneridge Electronics och AB Volvo. Projektet genomförs 2009-12-01 – 2013-06-30 med totalbudget på 12 MSEK varav 6 MSEK söks från Vinnova.

Abstract

Future production will be located in plants that flexibly and efficiently can produce new products, complying with environmental requirements. New sustainable production and products, e.g. new hybrid engines, will affect the whole production flow by increasing complexity and dramatically increase the number of components and variants. This project will develop generic models and methods to support strategies, planning, managing, and optimizing of complex production. The added complexity is studied and a definition of complexity is developed, along with methods to manage complexity, competence, and information requirements. Results will contribute to modelling and IT-support tools for calculation of the total requirement of indirect and direct man-hours in production. The principal investigators and project leader is Swerea IVF in collaboration with Chalmers, Volvo Cars, Parker Hannifin, Stoneridge Electronics, and AB Volvo. The project is carried out 2009-12-01 – 2013-06-30 with a total budget of 12 MSEK, where 6 MSEK is requested from Vinnova.

1 Relevance of the project

Continual demands on production are quality, cost, production volume, deliverability, enhanced efficiency, and added flexibility. In addition, a major challenge for industry is to achieve sustainability. The new range of products that reduce environmental impact requires new production methods and challenges the entire production value chain, e. increasing complexity of products and thus processes and production. The overall goal is to support management of dynamic production changes and added complexity, thus optimizing the use of production resources towards sustainability.

1.1 Sustainability challenge – a cause for production complexity

In order to obtain competitive advantages, production systems in Sweden have to be slim, readily adjustable, and must meet the sustainability and environmental requirements. Sustainability refers to ecological as well as economical issues and social/human: (1) Introducing new technology and processes in production meeting new environmental requirements; (2) Achieving economical and ecological sustainability of process and operation; (3) Improving work environment, ergonomics, and competence to manage new processes.

Sustainability thus sharpens requirements and makes optimization of production is increasingly complex. In particular the flexibility is effected: there is need for handling rapid new "crash" programs that may severely change technology, process, and products. Further, production realization process must handle increased complexity. For example, introduction of new engines (hybrid, electrical) in production of passenger cars, is expected to lead to an acute increase of the number of components and variants in parallel, shorter life-cycles for products, and frequent changes (in technology, products, processes, and suppliers). This affects the processes and the whole production flow — body-shop to assembly. Volvo Cars Corporation expects the number of car components to increase by 50-100% within 3 years.

1.1.1 Production optimization – indirect work, re-balancing, and standardized work

Also for development of sustainable production systems, optimization has to take place on station-, line-, shop- and plant level. Man-hour planning and control are key issues and consists in this context of "direct work", "indirect work", "competence", and "information". Methods and tools are available for planning and calculating in advance the total man-hours needed in different operations and applications. However, there is a lack of deeper knowledge on the content of indirect work in these calculation models. This is a problem as the amount of necessary indirect work tend to largely increase with the degree of production complexity. According to Volvo Cars, it is becoming increasingly difficult to know in advance and calculating the total man-hours needed for assembly (direct and indirect). Specifically knowing what is the effect of time, cost, and balance when introducing more product models/variants are introduced into the same processes/line. Increased knowledge of the content of the indirect work makes it possible to adapt competence development and information strategies to different complexity situations.

The production system must continuously be optimized and re-balanced , due to changes in product mixes, volumes and sequences. To be able to cope with the changes, correctly abstracted and detailed models, proper user interfaces, optimization engines are needed, as well as an organization committed to using such tools. In industry, IT tools for line balancing are available but analysis procedures are still inefficient. As the frequency of re-balancing will radically increase, further development of methods and tools is certainly required.

For manual assembly operations, standardized operation instruction sheets are important for efficiency and quality assurance. Standardized work instructions are not easily maintained, updated or changed to new variants or stations. Thus, a risk of increased production complexity is adding difficulty of using work standards. At the same time, quality requirements force stricter use of standards which stress the importance for leadership approaches to maintain and gain acceptance and ownership of standardized work procedures.

1.2 Expected results and users

These industrial challenges stress the need for exploring and defining the notion of "production complexity" in relation to operation, man-hour planning, information, and competence prerequisites. The COMPLEX project will deliver generic results in respect to company/plant and application. Generic results can be applied and implemented by industry to provide company specific means to manage added complexity (see Figure 1). Expected results include (see WP deliverables, chapter 3):

- An operational description of the "production complexity" concept. Improved ability for managing production complexity in participating companies. Models and methods to support man-hour planning, on plant, line and station levels

- Strengthened research group competence and network. Continuous collaboration and sharing of experience in academic networks.
- Academic publication of at least five scientific papers in reviewed conference proceedings, and submissions of two journal articles according to plan (see chapter 2.4).
- Dissemination of research results numerous for a, incl courses at Chalmers, e.g. in the international masters programme. Industrial and academic workshops and seminars performed.

1.3 The relevance of the project to the programme

The project refers to the call's sub-area "production strategies and production allocation". When deciding on allocation, direct labour cost is only one of many parameters. It is for example important to take into account skills, competence, and approaches for organizational learning. The project develops new knowledge and methods to manage and optimize production systems, providing input to production strategies. Working with a production strategy promote sustainability of systems, by providing a framework that takes into account a large number of aspects. Thus Swedish industry is offered methods for working efficiently with a strongly complex production, thereby strengthening competitiveness, making production possible in Sweden.

The COMPLEX project centres on the vague concept of complexity. The motivation for targeting complexity is that it makes the product realization process difficult, and has a potential to become a key to better manage future challenges. Extended knowledge and instruments are needed to measure and communicate the impacts of complexity. The project takes a long-term approach to strengthen the research area and establishing a strong knowledge base for further research. The goal is to strengthen the Swedish researchers' international competitiveness in the area. The project will facilitate: (1) Innovative production of products with low environmental impact which requires new solutions in materials, processes, and production; (2) Flexibility in mixed production of conventional and new engines in the same production; (3) Efficiency of manufacturing engineering and production processes; (4) Sustainability of production systems from ecological, economical, and social/human perspectives.

2 Aim and quality of the research

The aim of COMPLEX project is to contribute to development of sustainable productions systems by increased understanding of the concept of production complexity, providing means to measure, compare, and manage added complexity. Specific focus is set on optimizing "direct-" and "indirect work", information and competence needed during the industrialization process of new/modified environmental-oriented products. A set of problem areas are identified as crucial for production planning and operation, to facilitate rapid industrialization of new environmental-designed products: *Added product- and production complexity, Management of complexity and uncertainties, Plant man-hour prediction and planning,* and *Complex operation support.* This project assumes that increasing flexibility will increase the need for indirect work and competence/support in production. Also, that a practical and operationalized definition of production complexity is necessary in order to manage added uncertainties and difficulties. Further, increased knowledge of the content of indirect work is needed to support design of calculation models for man-hour planning, IT-tools and line-rebalancing work (which is addressed in the parallel Belgian project proposal).

There is need of a clear picture of what is meant with "complexity", and a need of method to describe, and measure, compare, and analyse the level of complexity in different applications. In this way, a process can be compared to another in regard of its complexity level. This evaluation may in turn support the prediction of the system's behaviour/features, e.g. the man-hour planning, costs, support needed related to management, information requirements, competence etc.

2.1 Production complexity

The scientific base of complexity research is interdisciplinary and encompasses many theoretical frameworks, in technology, biology, and life science. Also in production and manufacturing research, a broad array of systems analysis concepts dealing with the complexity has been presented, a comprehensive review was presented by Ueda et al. (2001). Complexity definitions are often tied to the concept of a 'system' and the set of parts which have relationships among them. In that view, complexity arises from the number of distinguishable relational regimes in a defined system. Weaver (1948) states that the complexity of a system is the degree of difficulty in predicting the system properties, given the properties of the system's parts. Further, in Weaver's view, there is disorganized complexity, and organized complexity. What is complex and simple is relative: Depending on competence, information, and tools, a system's complexity can be managed, reduced and perceived as less complex. E.g. the properties of a system of organized complexity may be better understood using modelling and simulation. The COMPLEX project will focus on complexity aspects of physical production systems, and on the related social systems needed to manage uncertainty in production. An important parameter in COMPLEX is the relation between system complexity and the total human man-hours required for production.

Work package 1 addresses a necessary delimitation of complexity definitions that enhance the academic and industrial understanding of the impact of complexity, and also making operational some of the concepts presented by Ueda et al. (2001). The handling of complexity and uncertainty may be further complicated by the introduction of automation in production systems. Unless the functionality of the automated system can be adequately described, it may add to the complexity and increase chances of uncertainties.

2.2 Management of uncertainty related to complexity

According to Grote (2004) adequate management of uncertainty in complex systems is crucial for safe and efficient system design. Rules management and complementary system design are pointed out as two particularly promising avenues for uncertainty management, and depends to a high degree on the systems designers and planners understanding regarding the roles of humans and technology in handling uncertainty. Further, planned changes of complexity levels in production, are often bordered with various difficulties. It is not unusual that product introduction phases are filled with activities of a fire-fighting character (Almgren 1999; Fjällström et al 2009), which leaves limited time for reflection and learning (Liker and Meier, 2007). Juerging and Milling (2005) argue that so far proactive ways of handling problems is lacking, and typically reactive measures from project management are used. This is unfortunate since previous research has shown that proactive strategies in production support the achievement of operational performance Gonzáles-Benito (2005), and it is widely accepted that proactive behaviour is advantageous in today's workplaces (Bruch et al 2008).

2.3 Complex operation support

Human cognitive skills at different levels in the organisation are increasingly crucial when production systems are becoming more complex and subjected to changes and uncertainties (Grote, 2004). In complex environments, unknown events are assumed to increase and is by Reason and Hobbs (2003) referred to as novel problems, while known events usually are routine and trained-for problems. Thus, the added complexity increase the needs for supporting ergonomics, work environment, competence management, directly related assembly instructions, and training facilities and support. Members of the COMPLEX research team has since 1992 worked with manufacturing systems ability to adapt to constantly ongoing changes e.g. shorter lead times and faster change-overs due to market requirements (Stahre 1995; Johansson and Harlin, 1998; Johansson 1999; Harlin, et al 2007; Säfsten et al, 2008). From the studies of product introductions, it is also clear that pre-series production has an important role to facilitate learning and competence development These activities create arenas where involved personnel meet and discuss common topics, which provide opportunities for learning by doing and learning through experiments (Terwiesch et al, 2004; van de Merwe, 2004), and are examples of necessary "indirect work" in production. The content of "direct work" and "indirect work" is closely related to Rasmussens' classic levels of performance, i.e. skill-based, rule-based, and knowledge-based behaviour, the SRK-model (Rasmussen 1983) which is a useful base in this research.

2.4 Plan for academic publication

Results from this project are planned to be published in scientific journals, (e.g. Journal of Manufacturing Technology Management, International Journal of Operations & Production Management), and peer-reviewed conference proceedings (i.e. CIRP Conference on Manufacturing Systems, Swedish Production Symposium, SPS) with following working titles:

- The effect of higher complexity in pruduction systems related to lean production
- Level of Complexity in production systems - a framework
- Man-hour control challenges in automotive industry
- Indirect work in complex manufacturing systems
- Need for information and knowledge in a complex production system
- The use of level of complexity in a complex production system

2.5 Relation to EU research program and other research

The scope of COMPLEX adheres to several of the core areas of the forthcoming european research programme "Factories of the Future" (FoF). The tentative roadmap described by European Factories of the Future Research Association EFFRA[1] includes "Subprogramme 1 – Sustainable Manufacturing", specifically "FoF-1.9-2011: European Production System and manufacturing standards" and also Subprogramme 3 - High quality and high performance manufacturing. Further, the FoF contribution by the EU section for Information and Communication Technologies[2] has related topics "ICT for better understanding and design of manufacturing systems and for better product life cycle management", specifically "Design environments" and " Knowledge and analysis"

The project will collaborate with a parallel project for which funding will be applied from Belgian Flanders' Drive, during autumn 2009. Both projects focus on the same challenges and are aimed at providing better means to manage complexity. The projects will have separate focuses. The Belgian project is focused on defining potentials for IT Support for quick analysis of gaps, mix effects, rebalancing, and integrated simulation model. Further on-going collaboration is described in chapter 3.4.

3 Research methodology and approach

3.1 Theoretical base, assumptions, and research questions

The theoretical framework guides this research, by providing a definition of the principal variables and factors that are relevant to the problem, and the relationships between the variables. The framework supports the determination of the research problem and a feasible approach. For the COMPLEX project the theoretical base include (1) Complexity science, complex adaptive systems; (2) Competence, skill/rule/knowledge based tasks, information exchange; (3) Levels of automation, human-machine collaboration, disturbance management; and (4) Scientific management, lean production, and socio-technical system principles. The production system is considered having an organized complexity, i.e. non-random interaction between the parts The coordinated production system have properties that are not carried by the individual parts. Theories and models of Complex adaptive system (CAS) are used for studying production system.

An underlying assumption in this project is that a company which has described their production system, e.g. based on Lean principles, facilitate prediction and consequence analyses of the impact of increased complexity. This holistic perspective minimizes the risk of sub-optimization and may contribute to development of sustainable production systems. The COMPLEX project will utilize the production system framework developed in the Lean Navigator when elaborating on the term of complexity at a plant level (Harlin et al, 2009).

Knowledge related to complexity management and models is utilized from research in manufacturing and from other fields. The purpose is to achieve models and methods that are generic to manufacturing industry at a plant level, and when appropriate, generic in different applications as body shop, paint, assembly etc. These models and methods contribute to development of support tools needed for management and man-hour planning, competence development approaches, and design of the work organization when increasing complexity and flexibility. A contribution of this

[1] European Factories of the Future Research Association (EFFRA). 2009 Factories of the Future, Indicative Work Programme (2011-2013), (Version: 30 January 2009)

[2] Commission of the European Communitie, 2009 Position Paper, ICT Theme Contribution to the "Factories of the Future" Initiative (draft rev 9).

project is to investigate indirect work in production based on theories on previous research on uncertainty management, disturbance handling, and behaviour- and information models. In this research, Rasmussens SRK-model (Rasmussen, 1983] is appropriate as well as the infrastructure developed in the Proact project (Vinnova D Nr. 2006-00735).

To correspond to the overall aim, the following research questions (RQ) are addressed and elaborated in work packages 1 – 3:

RQ1 What should be included in a definition and description of "production complexity" to support measurement and development work of efficient, highly flexible and sustainable production?

RQ2. How are the different parts of the total indirect man-hour work affected by the increased complexity?

RQ3 Which competence and information support is required and how can this be provided, in order for production personnel to manage the added complexity?

RQ4 What factors should be included in a line re-balancing methodology and calculation models for man-hour planning

The project is divided into 7 work-packages (WP) with leaders for each WP indicated in figure 1.

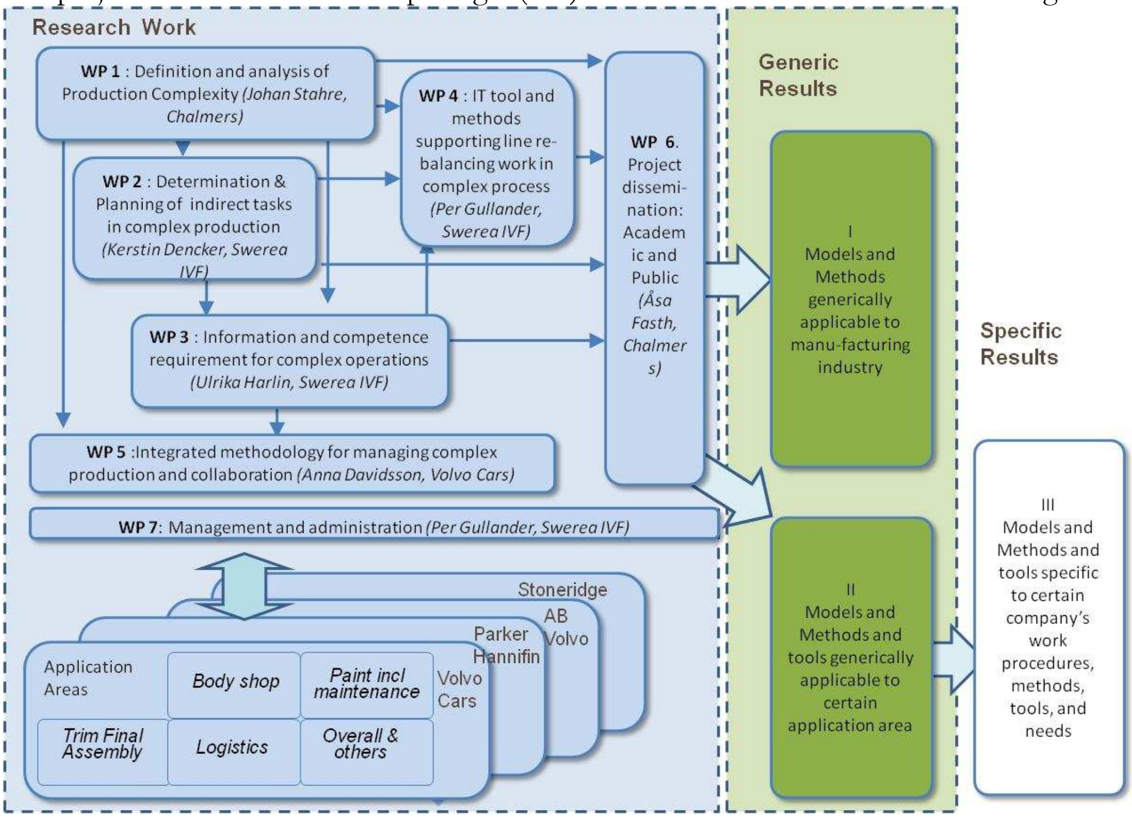


Figure 1. The project is divided into 7 work-packages (WP) with leaders for each WP indicated.

The research procedure facilitate generic results in two levels: Applicability to "manufacturing" and "certain applications" respectively and contributes to industrial implemtation of subresults in the participating companies in their approaches of complexity management and man-hour planning.

3.2 Case Study Methodology

The research questions RQ 1 – RQ4 are addressed in empirical case studies based on the theoretical framework (Yin, 2003.) By that, the empirical data sets the base for formulation of models, methods and theory development. These industrial studies are needed to achieve practioners knowledge about the complex and individual systems. An inductive qualitative research approach is adopted as the research questions addressed, require knowledge of production complexity related to human intervention. The case study approach is based on a framework developed to include investigation of major planned changes in production, and is in the COMPLEX-project further developed to address the production systems chracterized by increased complexity (Harlin et al, 2007). Deeper case studies will be carried out at Volvo Cars Plant in Göteborg. In practice, an initial study serves as a platform for investigation of complexity in an assembly application at VCC. The following step is to carry out complementary studies at other applications , i.e.body shop and paint involving other companies (AB Volvo and partners in the value chain: Parker Hannifin and Stoneridge Electronics.

3.2.1 WP 1: Definition and analysis of production complexity

Research Questions: What should be included in a definition and description of "production complexity" to support measurement and development work of efficient, highly flexible and sustainable production?(RQ1)

Approach: Define the concept of "complexity" of production systems, in order to face trends for future and handle expected frequent changes in production. This need to separate objective measurable aspects from subjective competence-related aspects of complexity. The analysis need to cover (1) the causes of raised complexity - more product models/variants into the same processes/line, and more complex production & logistic flows in high tech environment.; (2) the effects on the product realization and production development; and (3) the effects on personnel, the perceived complexity. Focus on complex workstations, technical areas, complicated flows. The method is based on scientific theory & experience from studies in assembly. Its expandability is evaluated and tested on other application areas (Body shop, Paint, Maintenance, Trim & final assembly, and Logistics.) as well as on plant & shop level.

Deliverables: Case study plan for WP1 (D1.1). A definition of complexity feasible for production on factory, line and station levels (D1.2). A method for measuring and communicating shop/station complexity analysis providing a possibility to evaluate "Level of Complexity" (D1.3).

3.2.2 WP 2: Determination & planning of indirect tasks in complex production

Research Question: How are the different parts of the total indirect man-hour work affected by the increased complexity? (RQ2)

Approach: The purpose is to provide means to better determine & plan the needed indirect man-hour resources in workshops with high level of complexity. This includes elaboration on affect on the added need for flexibility, more frequent changes, increased no of variants, etc. The work initiates with studying the manning in production and current methods, models, formulas. The effects of increased complexity (see WP 1) on the activities in production is analyzed and modeled. These activities span from direct (operation on product), to very indirect (organization support). Then a refined formula & method are developed. Studies, development, and testing are carried out on selected operation areas in assembly and body shop (having very different characteristics concerning direct and indirect work content). The feasibility and the generic application in other areas of production is analyzed. Studies include data collection, interviews of key personnel, monitoring of production.

Deliverables: Case study plan for WP2 (D2.1). Model of the effects of increased complexity on organization and operations (D2.2). A method for planning the total plant man-hours with complex production processes, providing the relation between indirect and direct manning needs (D2.3).

3.2.3 WP 3: Information and competence requirement for complex operations

Research Question: Which competence and information support is required and how can this be provided, in order for production personnel to manage the added complexity? (RQ3)

Approach: Identify changes in competence requirement and management when increasing complexity of the operations, frequency of changeovers, requirements of fast ramp-up (e.g. need for flexibility in moving operators between assembly operations and technical tasks). Identify the information requirement (instructions, rule, databases, board, lights, etc.) to perform the new set of production work (Identified in WP 2) in a efficient way, specifically studying the balance with into the solutions and principles as advocated by Lean Production methods. Methods for determine and support these information and competence requirement is then identified and tested in a pilot case at VCC. Indirectly, the methods will also provide means to secure safety and health of employee. Also analyzed is the feasibility of using a "mental compensation factor" to meet the need for extra operation time (for mental change-over/setup) while performing complex (rare) jobs, in complex stations.

Deliverables: Case study plan for WP3 (D3.1). Description of requirements of information and competence in relation to added complexity and more indirect work tasks (D3.2). Methods to determine and support fulfillment of these requirements (D3.3).

3.2.4 WP 4: IT tools and methods supporting line re-balancing work in complex process

Research Question: What factors (i.e. activities, methods, tools, and roles) should be included in a line re-balancing methodology and calculation models for man-hour planning (RQ4)

Approach. This WP is aimed at defining potentials of developing a method and IT tools for easy & automated line re-balancing (gap analysis and optimization), related to manual & indirect work. The method needs to manage analyzing the effects of combining more models & lines, and create standardized assembly operation instruction sheets. The Belgian project has an emphasis on development work in this WP. The Swedish COMPLEX project explores the need, the context of complexity management, and (based on WP 1-3) defines the methodology that will provide the framework for the tools and methods. The initial analysis, case studies and development of preliminary methodologies, are common work between Swedish and Belgian projects.

Deliverables: Definition of complex line re-balancing method needs and potentials for sustainability (D4.1). Model of a complex line re-balancing method indicating activities, methods, tools, and roles (D4.2).

3.2.5 WP 5: Integrated methodology for managing complex production and project collaboration

Approach In this WP, results from WP 1-4 is integrated where the aim is to contribute to a integrated methodology to manage complexity in systems and operations The Swedish project focuses on the models and methodology and defining an integrated methodology to better managing complex systems and operations. This methodology need to consider differences between application areas, industrial contexts. The Belgian project focuses an overall integrating simulation model that contains main results from WP 1-4. The initial analysis and final verification is common tasks between Belgian and Swedish project. An explicit part of this WP is the collaboration with the Belgian project.

Deliverables Integrated methodology to manage complexity in systems and operations (D5.1)

3.2.6 WP 6: Project dissemination

Approach Dissemination is organised through activities by project partners (University, Industry, Institute), explicit publications public and academic, folders, web site (with continuous news/publication), conference participation, participation in Vinnova programme conference, workshops, and status and final reports to Vinnova. Public dissemination is made in parallel with writing academic journal and conference articles. Results will be presentation within relevant the FFI cluster groups. An internal project website will be set up for exchange of information materials (presentations, minutes, reports, etc). Public magazines and newsletter includeVerkstäderna, Swerea IVF's Teknik & Tillväxt, and Medlemsinformation Intressentföreningen.

Deliverables. Academic publications including Conference papers, Journal papers (see publication plan). Public publications including a web site (D7.1)

3.2.7 WP 7: Management and administration

The project is managed by Per Gullander, Swerea IVF, and by the appointed WP leaders. These meet regularly to follow up results and plan activities. Also important is to coordinate activities and information exchange with parallel projects. Specific attention needed for integration with other research project, specifically the parallel project in Belgian

3.3 Project partners, roles and organization

The project is lead by Per Gullander, Swerea IVF with an overall responsibility for the project. In addition, each work package has an appointed leader (Table 1 and Figure 1).

3.4 Collaboration with other projects

The project is planned to collaborate with other projects conducted concurrently. A number of projects are considered valuable for the COMPLEX project, and vice versa. **Parallel COMPLEX project in Belgium:** The project will collaborate closely with a parallel project COMPLEX for which funding will be applied from Belgian Flanders' Drive, Dec 14 2009. Both projects focus on the same challenges and are aimed at providing better means to manage added complexity.

The projects will have the same set of work packages but have separate emphasis. While the Swedish project has a scientific approach producing more generic results, the research in the Belgian project is more stressing development and focused on defining potentials for IT Support for quick analysis of gaps, mix effects, re-balancing, and integrated simulation model. The Swedish COMPLEX will provide: Complexity definition, measurement, change, effects, indirect man-hour planning model, supporting method line balancing. Expected input from the Belgian COMPLEX include: knowledge / situation, flexibility, efficiency, balancing optimization needs. Models resources in line. For securing good collaboration Bart Debacker, Anna Davidsson and Per Gullander are participating in both projects, with explicit budget in WP 5.

Table 1. Partners, personnel, role and responsibility

Organisation	Personnel resources (% of partner's COMPLEX budget)	Role and area of responsibility
Swerea IVF, Göteborg & Stockholm	Per Gullander, PhD (50%) Ulrika Harlin, LicEng (35%) Kerstin Dencker (15%)	Research. Leads WP 2, 3, 4 and 7. Project management. Dissemination and academic publications. Collaborating with Belgian COMPLEX project
Chalmers Univ of Techn, Göteborg	Prof Johan Stahre, PhD. (40%) Åsa Fasth, Lic.Eng (60%) Dept Product and Production Dev.	Research. Leading WP 1 and 6. Dissemination and academic publications.
Volvo Cars Corp, Göteborg (VCC)	Anna Davidsson, PhD Raf Forier, Bart Debacker, Mattias Eliasson	Provide Case Studies. Research & development work. Leads WP 5. Cooperation with parallel Belgian COMPLEX project
Parker Hannifin, Borås	ProACT project's contact person	Provide reference study (supplier to the truck industry, hydraulics components)
Stoneridge Electronics, Örebro	Stefan Höög	Provide reference study. (supplier to the automotive, truck, bus and off-road vehicle markets)
Volvo Technology/AB Volvo, Göteborg	Lena Moestam Ahlström, PhD Gunnar Bäckstrand, Volvo Powertrain	Provide reference study at AB Volvo Company. Collaboration with project FACECAR.

FACECAR. (Flexible Assembly for Considerable Environmental Improvements of Cars).This FFI project was approved in Sept 2009 and studies similar area as COMPLEX. However, it delimits to assembly, while COMPLEX is aimed at application generic models. Further, the issue of increased complexity, effects, and means to handle complexity is the focus in COMPLEX but not a specific issue in FACECAR. *Gunnar Bäckstrand (Volvo), Dick Larsson, and Lena Moestam Ahlström participates in both projects top ensure information exchange and collaboration.*

MyCAR is an EU Integrated Project that develops and integrates technologies that will facilitate the vehicle assembly, by studying simulation technology, supply chain simulation, and Knowledge-based Assembly Plant. The COMPLEX project will study the tools and methods developed in MyCAR. Chalmers, Volvo and Volvo Cars are participating in both projects securing information exchange *(Åsa Fasth, Johans Stahre, Lena Moestam Ahlström).*

At Swerea IVF a number of related projects are conducted that provide input to COMPLEX: **Framtidens industriarbetare.** (IF Metall, Teknikföretagen, Vinnova D-Nr 2009-02794), studies and model changes in requirement on basic competence of industrial worker project; KNOP (Lärande och kompetensdriven produktintroduktion för svensk tillverkningsindustri, Vinnova Dnr 2006-00124) Learning and competence driven product introduction *(Per Gullander and Ulrika Harlin)*

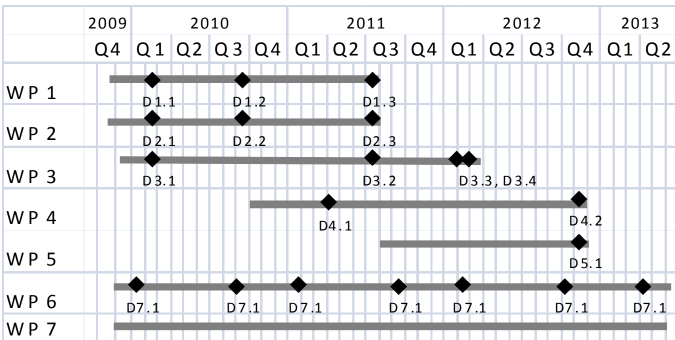
3.5 Project schedule

Research work is conducted over 3.5 years, from 1 december 2009 to 30 June 2013, where the last half year is intended for industrial application/implementation and dissemination. (See Table 2)

3.6 Project budget and financing

The total project budget is 12 MSEK. Funding from Vinnova is sought for

Table 2. Project schedule



6MSEK for research work performed at Swerea IVF and Chalmers. The expected use of project funds is specified in the table 3 and 4 below.

Table 3. Budget costs and funding for each partner and year

Budget [k SEK]	Swerea IVF						Chalmers						Totalt
	TOTALT	2009	2010	2011	2012	2013	TOTALT	2009	2010	2011	2012	2013	
WP 1	**600**	20	300	200	50	30	**500**	10	200	200	90		**1100**
WP 2	**650**	20	300	250	50	30	**450**	10	200	150	90		**1100**
WP 3	**650**	20	200	250	150	30	**450**	10	150	200	90		**1100**
WP 4	**350**		50	250	50		**250**		50	150	50		**600**
WP 5	**300**		60	120	120		**300**		60	120	120		**600**
WP 6	**550**	10	150	140	150	100	**550**	10	150	140	150	100	**1100**
WP 7	**350**	40	100	80	80	50	**50**	10	10	10	10	10	**400**
TOTAL	**3450**	110	1160	1290	650	240	**2550**	50	820	970	600	110	**6000**

Table 4. Industrial partner planned work

	TOTALT	2009	2010	2011	2012	2013
Volvo Cars	**4500**	100	1900	1000	1000	500
Parker Hannifin	**1750**		500	500	500	250
Stoneridge Electronics	**1750**		500	500	500	250
AB Volvo	**700**		200	200	200	100
	8700	100	3100	2200	2200	1100

4 Exploitation and usefulness of results

Project results are derived on two generic levels (all manufacturing industry and certain type of manufacturing industry) and one specific level (company specific), thereby making it easier to better direct and adjust results for different purposes.

4.1 Project deliverables and relation to the call

Benefits and expected results are scientific and practically feasible results including:

1. A framework and method for measuring/ analysing and communicating level of complexity)
2. Increased knowledge and models relating the impact of production complexity to "direct work" and "indirect work" in production systems
3. A parameter-based evaluation tool to calculate needed indirect manpower
4. Practical guidelines & mental pressure compensation factors on complex stations & jobs
5. Methods for providing supporting information infrastructure and assuring sufficient competence to manage added complexity;
6. Design support for development of IT-tools and methods for man-hour planning;
7. Design support for information infrastructure and assuring sufficient competence to manage added complexity;
8. Pilot Application in VCC, and knowledge of methods in major Swedish manufacturing industrial companies;
9. Publications and dissemination in both academia and public.

The generic results are translated into company specific results and will be directly incorporated in the man-hour control process of VCC and are thereby implemented in consumer goods company providing for more sustainable production in Sweden. By this also possibilities for implementation in other companies are shown. This supports Swedish manufacturing industry in providing for competetive manufacturing, and thus keeping or increasing production in Sweden. Cooperation with COMPLEX Belgian part creates a new network within EU and Strengthened competence and international collaboration of research group for future work; Research education (after lic) for at least two persons is incorporated in the project.

4.2 Plan for exploitation of results

Initially, the results from WP1 will be used at the participating companies in helping objectively defining the level of complexity of: assembly stations, automated area's, material & product flows, areas and complete plant. WP2 developed parameter based evaluation tools, to calculate needed indirect manpower, will be applied at VCC to define level of authorized manning in area's, shops and plants; in relation to their traditionally calculated workload with add on for complexity of their activities. This will affect actual plant manning budget and business plan work. Further the model will be shared and applicated in other applications in accordance with the needs at Parker Hannifin, Stoneridge Electronics, and AB Volvo.

The practical guidelines and calculation factors developed in WP3 will be applied in practice by the Production management of the different shops, to give the needed additional support for the involved personal confronted with increased complex production situations in training, preparation matters, planning, modern instruction interfaces and personal recognitions allowances. The results from WP1+2+3 will give the manufacturing engineers the opportunity to prioritize, calculate, motivate and initiate actions towards process and product improvements in order to decrease complexity in the production and support operations.

WP4 developed demonstrator in the parallell propsed project in Belgium will be used at VCC to further develop and upgrade existing work balancing tools with automated balancing features for direct work. Additional the developed tool should help production engineering to speed up analyzing work on the effects of combining more models & lines and faster creating changed standardized assembly operation instructions.

WP5 contains a full package of developments done in the previous packages. After integration of the work packages results in the companies´ environment; this integrated model will be used as the standardized tool for production manning / capacity planning and model mix simulations. Industrial suppliers in the value chain and other industries in general can also use the WP's results for similar purposes and support; adapted at their own production environment and increased complexity from product and process point of view.

4.3 Plan for dissemination of results

There are several possibilities for knowledge dissemination and experience sharing thanks to the cross-organizational industrial and research collaboration. Several approaches, networks and organizations will be utilized for visualization and knowledge dissemination and facilitate that project results can be used by different interest groups. Further sub-results from the project will continuously be available on the web-site www.leanresan.se and shared in academic and industrial work-shops which facilitate early use in other companies and researchers than those involved in the project.

The participating companies will develop their working methods and activities in the course of the project, at the same time as researchers contribute to generalization and visualization of results within Swedish industry. Swerea IVF will visualize sub-results from the project in industrial implementation within their national network. Also the research teams on-going involvement in other research projects (E.g. MyCar, Face car, Framtidens Industriarbete) and established networking arenas such as the xxx, will be used for knowledge dissemination. Other opportunities are utilization of subresults in education, e.g. Chalmers will disseminate results through teaching at undergraduate and graduate levels at Chalmers, industrial workshops organized by the participating companies and Swerea IVF.

5 Diversity & risk analysis

Product realization involves several organization units, teams, and individuals. A cross-disciplinary collaboration is therefore necessary for the ability to forecast and manage consequences of changes, such as added production complexity. Diversity in respect to competences, capabilities will increase - regarding individual competence contribution is beneficial for innovativeness and creativity. Managing this and utilizing the diversity is important and need to be considered in methods and models for sustainable production.

The project will run for 3,5 years, which is a long time from an industrial point of view. There are thus a risk that the participating companies and case studies initially identified need to be modified.

Table 5. Risk analyses, actions and countermeasures

RISK (probability)	ACTION to reduce negative consequences
Company drop-out or want to reduce their co-financing (medium risk)	All participants shall be notified. If co-financing for the project does not reach up to at least 50%, attempt increased co-financing from other partners/new partners. The Steering Group decides if the project is affected
Personnel change position or quit (higher risk)	The Steering Group decides if the project is affected. Active work to teach new member, contact person
Major change in Schedule needed (low risk)	The Steering Group Decides. For major changes, project manager contacts Vinnova
Project leader change (low)	The Steering Group decides. Vinnova is informed. Collaboration with a co project leader.
Academy drop-out (low)	Academic input is taken over by existing partner, Vinnova is informed
Company conditions change/part of a project need to be deleted (low)	At least 2 contact persons at each company. Impact analysis of the project's continuation. Request responses from all project participants. Approved by Steering Group. Vinnova is informed. Budget is transferred to other parts of the project

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