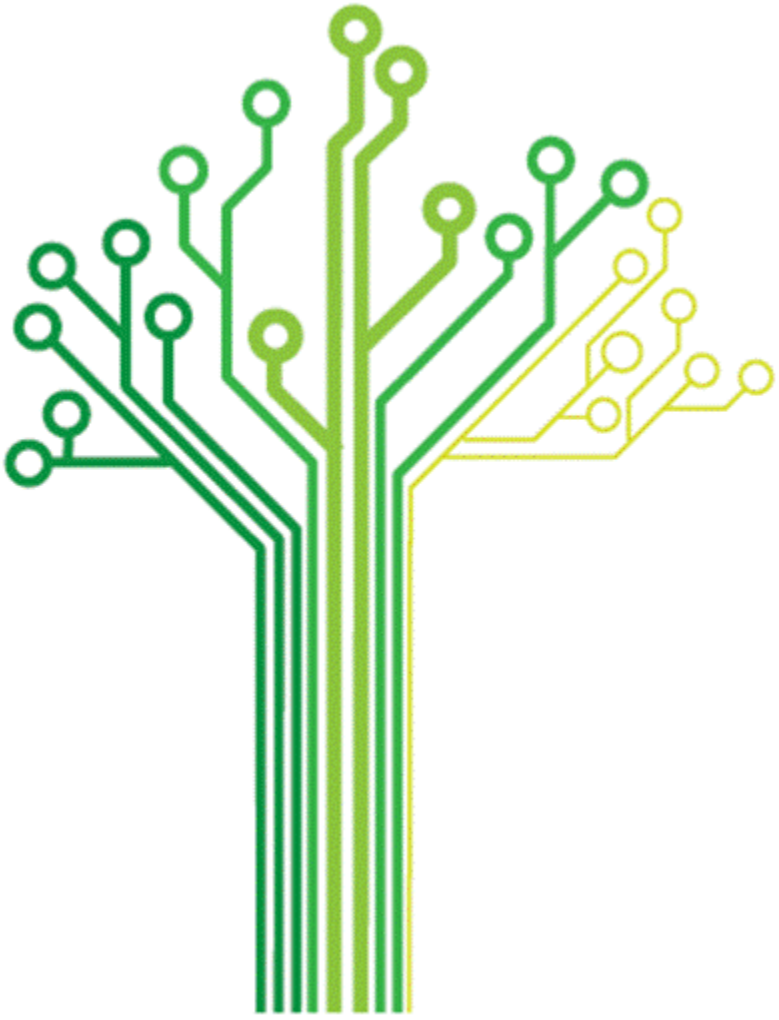
Green Production Systems



A project within the FFI Sustainable Manufacturing Program

Monica Bellgran, Magnus Wiktorsson, Martin Kurdve, Karin Höckerdal
Mälardalen University 130131

Content

FFI in short

FFI is a partnership between the Swedish government and automotive industry for joint funding of research, innovation and development concentrating on Climate & Environment and Safety. FFI has R&D activities worth approx. €100 million per year, of which half is governmental funding. The background to the investment is that development within road transportation and Swedish automotive industry has big impact for growth. FFI will contribute to the following main goals: Reducing the environmental impact of transport, reducing the number killed and injured in traffic and Strengthening international competitiveness. Currently there are five collaboration programs: **Vehicle Development, Transport Efficiency, Vehicle and Traffic Safety, Energy & Environment and Sustainable Production Technology.**

1. Executive summary

The overall vision of the FFI funded Green Production Systems (GPS) project executed 2009 – 2012 has been to develop the green production area to be a competitive means to Swedish manufacturing industry in general, and automotive industry in specific. The project has emphasized the need for the necessary mindset and incentives of manufacturing industry to define and implement a 'green' strategy in integration with the common Lean philosophy and its infrastructure for daily operations. The basic idea of the project has been to broaden the engagement for environmental improvements to include all employees of the factory. To do so, new knowledge and supportive tools have been developed to facilitate the needed visualisation, control and management of the environmental aspects within the production system. The basic approaches applied in the project has focused reduction of waste and cost caused by environmental aspects and the industrial potential in adding value to the production system by green strategies and actions.

The project was initiated by Haldex AB and has been performed by researchers at Mälardalen University in close co-operation with a number of actively participating organisations; Saab Automobile, Volvo Construction Equipment, Volvo Technology, All-Emballage och ABB. Vinnova has through the FFI program Sustainable Manufacturing funded the GPS project with 2,75 MSEK, which has financed the recruitment of a PhD student, supervision, project management and results dissemination. In total, the partner companies co-funded with 4,6 MSEK, whereof Haldex contributed with the main part according to the agreement. However, the total industrial co-funding has exceeded the initial budget extensively.

The project aligns with the FFI programme's objectives related to sustainability and competitiveness. A number of different studies and case studies have been performed within the GPS project. The concrete results are new knowledge about the "green production system" concept including identification of typical enablers and barriers for performing environmental improvements within production. Two methods have been developed, where the Green Performance Map is the most extensive and tested one including a procedure in five steps of how to identify, analyse and prioritize environmental aspects to be addressed by concrete actions for improvements. It is based on an input-output model divided into eight categories, and helps visualising the environmental aspects and the amount and cost of each aspect on the selected systems level (from factory level to team level). The Waste Flow Mapping tool is for visualisation of waste (output) supporting decisions on how to recycle and reuse wasted material, including an analysis of the bill-of-material (input). Further, the Environmental Value Stream Mapping method (E-VSM) has been tested as an expert tool, functioning in the same way as the basic VSM but with an environmental focus.

2. Background

To enable competitive industrial production, designing and operating efficient and sustainable production systems is crucial. Even though the environmental impact of industrial and commercial activities has become more vivid and severe, evidence points to a slow diffusion of industry-led ideas and actions for improving the environmental performance. Manufacturing industry has still a bit to go on the journey towards designing and operating environmentally benign production systems, reaching climate neutral factories. However, it needs to be pointed out that in comparison; Swedish industry in general has a rather strong ambition and international reputation towards environmental sustainability.

Thus, increasing raw material and energy prices as well as potential penalties for lacking compliance provide cost related incentives for manufacturing companies to reduce the environmental impacts. Since production typically determines several environmental impacts such as exploitation of resources, contamination of soil, water and air, generation and emission of greenhouse gases etc., an important opportunity to reduce the environmental impact is found within a company's production activities. In this, environmental issues can be viewed as either constraints or opportunities for competition. Companies can choose to adopt different positions ranging on a continuum from re-active behaviour, merely complying with environmental laws and regulations, to pro-active positions where competitive advantages are sought for. Either way, the increased environmental concern requires manufacturing companies to develop strategies, technologies and practices that will reduce the environmental impact from production.

One of the challenges for manufacturing industry has been to go from the corporate level – where the environment is determined to be a strategic core value to the company – to actual implementation and engagement of all employees in making continuous environmental improvements. The environmental impact from manufacturing operations is perceived to be low in relation to a product's whole life cycle, which reduces the driving force. Another reason is that many companies are still in the phase of moving from compliance with regulations to recruiting an environmental expert to drive the Environmental Management System (like ISO 14001) and general environmental improvements. Further maturity is needed in the organisation to actually create an awareness and understanding of the environmental concerns among all employees.

The *Green Production System* (GPS) project has focused on the process of how to increase speed of environmental improvements in manufacturing operations by exploring the current state identifying the gaps and potential, and by developing supportive tools and methods in order to enhance the process. The GPS project was initiated by the Swedish automotive supplier Haldex in 2008/09. It is a project performed in cooperation with AB Volvo, Saab, ABB, All-Emballage and researchers from Mälardalen University. The overall idea of the project has been to address environmental improvements from an operations perspective and to broaden the engagement.

3. Objective

In the GPS project the mindset guiding the research has been "*value adding* and *cost reduction"* by environmental strategies and actions within the production system. The overall objectives of the project have been the following:

- To set the preconditions and frames of what a green production system is
- To identify best practices of green production systems
- To visualize the environmental impact and added value of a production system
- To find ways of following-up and managing a green production system
- To develop guidelines for value improvement and cost decrease by environmental strategies and actions within, and directed towards the production system

Here, manufacturing is considered as the total business of a manufacturing company, while production is subordinated manufacturing and means the process of physically making a product. The production system is defined as the actual system where the product is realized, comprising machining/parts manufacturing, assembly or both. The elements of a production system are normally facilities, machines and equipment and people, adding also material/products and IS/IT in the systems definition (see Bellgran and Säfsten, 2005). Green in the context of a production system is here defined in analogy with Toyota, meaning a production system that fully utilizes natural resources, while operating in harmony with the natural environment. Consequently, resource efficiency is a natural part of the green dimension.

4. Project realization

An interactive research view has been adopted implying close cooperation between the researchers and the industrial partners, both in identifying the environmental challenges in manufacturing industry, and in developing the tools. A qualitative approach has guided the data collection and analysis made in the project, and the case study methodology has been found most relevant for the purpose implying a freedom of choice concerning the use of necessary techniques for the data collection, such as interviews, observations and study of documentation. Figure 1 visualizes in brief a number of case studies performed within the GPS project, funding the development of the final results.

By collecting and analysing the empirical and theoretical findings, common barriers facing the companies in their strive to reduce the environmental impact from production as well as enabling factors, supporting the progress towards increased environmental performance have been identified. Based on an analysis of the current state one example of a link of challenges impeding the process of environmental improvement has been identified.

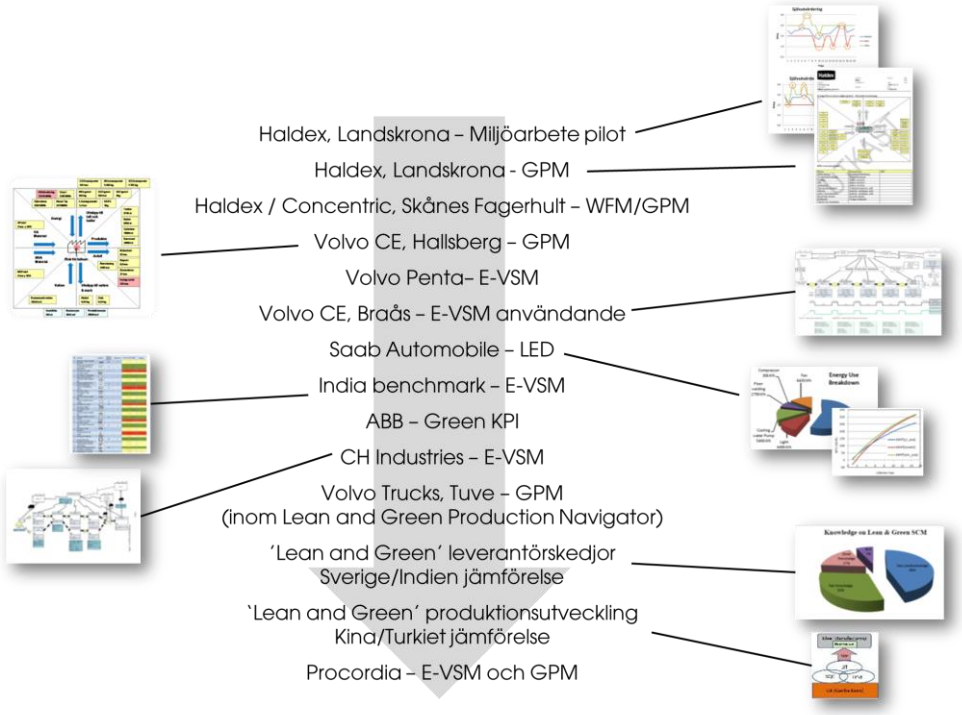


Figure 1. Illustration of studies performed within the GPS project (in Swedish).

A general pattern describing the stages from a reactive to a proactive approach was identified, indicating that an increased understanding of and commitment to environmental issues were crucial parameters in order to succeed. Based on the findings, a number of requirements for enhancing the process of environmental improvement in production were derived. It was concluded that developing a support in terms of an improvement process was one way of improving the current state. Using an existing visual structure as a baseline, a process for Green Performance Mapping (the GPM method) was developed in cooperation with the studied companies. Ultimately, the suggested process was evaluated against the stated requirements and suggested as a support for enhancing the process of environmental improvement in production within the manufacturing industry, thereby contributing to reducing the environmental impact from production.

A method for Waste Flow Mapping was also developed for the purpose of increasing sustainability. It is a Lean based tool for visualisation and analysis of waste material and is best used as cooperative tool for experts and operators. The E-VSM method (the Lean based tool, Value Stream Mapping, but extended by environmental aspects) has been tested in cases within the GPS project. In opposite from the GPM method and Waste Flow Mapping tool, E-VSM is regarded as an expert tool for visualization of detailed environmental aspects for processes.

5. Results and deliverables

There has been a debate in academia regarding wether lean is green or if lean production is counteracting the strive towards sustainability. Several researchers show that lean strives for reduction of non-value adding activities also reduces material and energy overuse. Other studies especially on logistics has shown that implementation of just in time may increase environmental losses. The results of this project takes similar conclusions as the US Environmental agency, that if properly conducted lean practice and environmental practice go hand in hand, in most cases the actions are the same for environmental practice as for lean practice and at other times they are supplementary and mutually beneficial. In both lean and environmental practice however there exists a risk of sub optimising if tools or methods are used with a narrow scope or point of view.

General results from the project

Table 1 and 2 summarise empirically identified barriers and enablers for environmental improvements, presented in the thesis by Höckerdal (2012).

Table 1. *Empirically identified barriers for environmental improvements (Höckerdal, 2012).*

Barrier	**Possible effect**
Environmental information is considered abstract and not easy to access	Not clear how environmental issues can be improved
Unclear system for evaluating environmental performance in production	Difficult to establish benefits of implemented environmental improvements
Environmental improvements often included at a late stage in development projects	Leaves less room for potential environmental improvements
Few employees have direct environmental responsibility	Potential improvements may be overlooked
Lacking understanding of what each person can do to reduce the environmental impact from their area	Limited commitment to environmental improvement
Short-term perspective (e.g., for return on investment/payoff)	Potential environmental improvements are ignored
Strong focus on cost and other traditional criteria	Environmental issues - not prioritized in conflicting situations
Production staff is not involved in the planning phase of ISO 14001 where aspects are identified and prioritised	The knowledge and experience of production staff is not integrated into the process of environmental improvement
ISO 14001 requirements are experienced as vague	Certification becomes an administrative issue
Difficult to define environmental performance indicators and set goals at lower levels in the production	Difficult to establish potential benefits of environmental improvement activities

Table 2. *Enablers for enhancing environmental performance in production (Höckerdal, 2012).*

Enabler	**Possible effects**
Growing awareness of environmental issues' importance	Increased commitment to environmental activities
Management commitment	Secures resources for environmental improvement

Availability of environmental expert competence in environmental function	Can be used as a support in the process of environmental improvement in production
Cross-functional environmental groups	Cross functional involvement of production employees in the environmental improvement process
Education of environmental ambassadors in production	Wider scope of environmental improvement activities
Exchanging experiences in environmental networks	Identification of best practice and good examples
Integrating the environmental perspective into operations management using the principles of lean production	Possibility of synergetic reduction of cost and environmental impact through a kaizen culture
Considering alternative production methods	Identification of BAT from the environmental perspective
Applying ISO 14001 for environmental improvements	Framework for the environmental improvement process
Visual control as advocated by lean thinking	Improved understanding of environmental issues

Translating barriers and enablers into requirements

From the analysis and synthesis made of the current state of the barriers and enablers of the studied companies, the following requirements could be derived, see figure 2.

Figure 2. *Empirically identified barriers and enablers translated into requirements for enhancing the process of environmental improvement in production (Höckerdal, 2012).*

Harmonising with the principles of lean production: Environmental and operational management share many characteristics, environmental issues can be addressed using operations principles building on the already existing Lean infrastructure for production improvements. Further, integrating the competence of the production organisation in the environmental improvement process will add value to the process. Even if organisations implementing lean theory naturally evolve to address environmental impacts, environmental benefits can be enhanced by ensuring that this occurs in an integrated, and hence, timely and efficient manner. Using lean concepts such as visualisation, ´go to gemba´, right from me, Kaizen practices and elimination of waste with an environmental focus is considered promising to integrate the environmental perspective in existing improvement processes. One of the basic lean principles not included enough in environmental management today is employee involvement. Hence, increasing employee involvement in the process of environmental improvement is requested.

Substantialising the requirements of ISO 14001: From an environmental perspective, the enhanced improvement process should support the existing environmental management

system, i.e. often ISO 14001. Since the environmental management of organisational processes and practices has traditionally been relegated to specialised environmental experts (with technical skills required to manage these activities), support needs to be developed in order to incorporate skills of these corporate environmental experts into the knowledge set of employees. Hence, the possibility to address the requirements of ISO 14001 on a local level; identifying and prioritising relevant environmental aspects for each process in order to supply the right incentives and a link to each employee´s work area, has been shown in this project.

Supplying a structured process: To allow production people on all levels to participate in environmental improvements and to develop good solutions, a systematic work procedure is requested making the environmental improvement process easy to learn, use and understand. Visualising process and result facilitates interaction and communication. Combining long term goals of improving the production system for increased customer satisfaction with the short term goals of generating profit will be key.

Enabling a proactive approach: Applying a holistic improvement approach, including all actors in the production system organisation, supports integration of environmental improvements in daily activities. By promoting individual learning, the general understanding will increase, enabling an increased commitment to environmental improvement. The organisation needs to find ways to make use of the commitment in order to enable a proactive approach. Involving employees from different parts of the production organisation in continuous improvement implies that all members contribute to improving company performance by continuously implementing small changes in their work processes.

Evaluating the environmental performance: A wide variety of indicators can be used to evaluate a firm´s environmental performance and depends on the context of each company. It is preferable when the process supports the identification of local performance indicators in order to evaluate implemented activities. These need to be designed such that individual and group incentives are easily traced to environmental improvements. Also, a clear link between environmental business objectives and environmental performance at shop floor level increases the understanding of how each part contributes to the overall environmental strategy. The need of a performance monitoring system that supports the operational activities has in this project been identified not only regarding the environmental objectives and actions but for other areas such as safety, quality and improvement work in general also.

Methods developed within the GPS project

As a response to the current state in manufacturing industry (and based on the five criteria above), a support for enhancing environmental improvements in production within the manufacturing industry has been developed, the GPM method, see figure 3. The goal is to achieve synergetic lean and green improvements by highlighting environmental issues in an effective improvement process. More information about the method can be found in Bellgran et al. (2012).

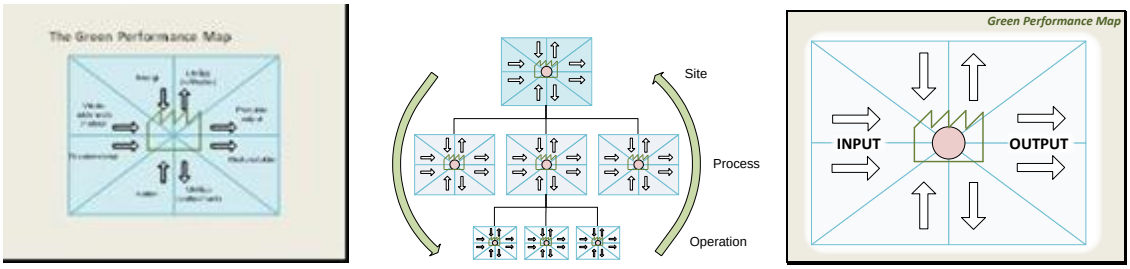


Figure 3. *The GPM method based on an input-output model where environmental aspects are identified, categorised and prioritised on selected system level.*

In figure 4 below, an implementation of the E-VSM tool from a case at Volvo CE is illustrated.

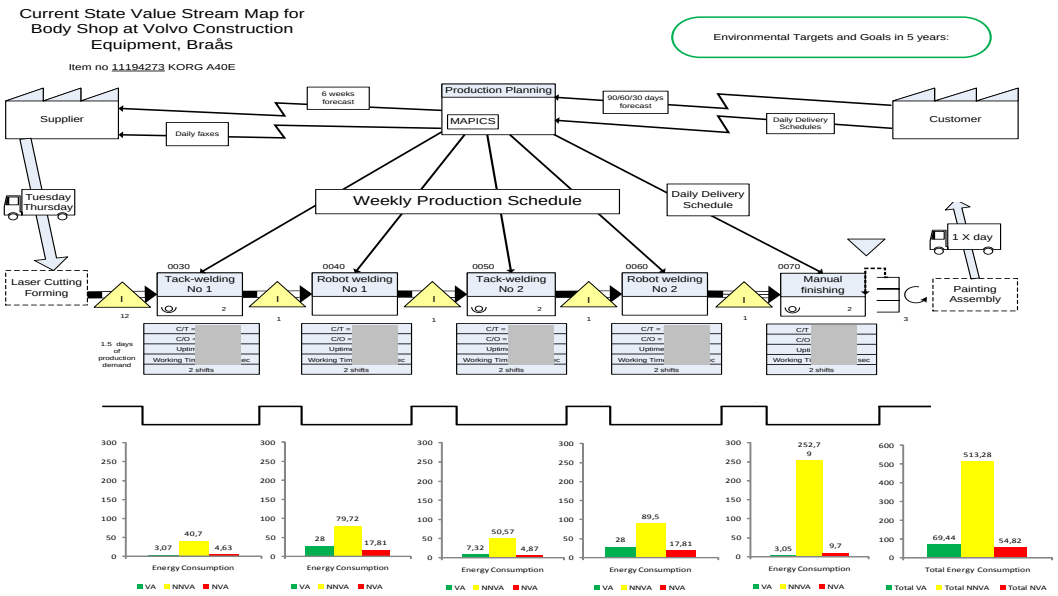


Figure 7. Environmental VSM for the Braås body welding, five stations.

Figure 4. *E-VSM performed at VCE in Braås.*

Another tool developed, Waste Flow Mapping, illustrated in figure 5 by a practical case at one of the case study companies.

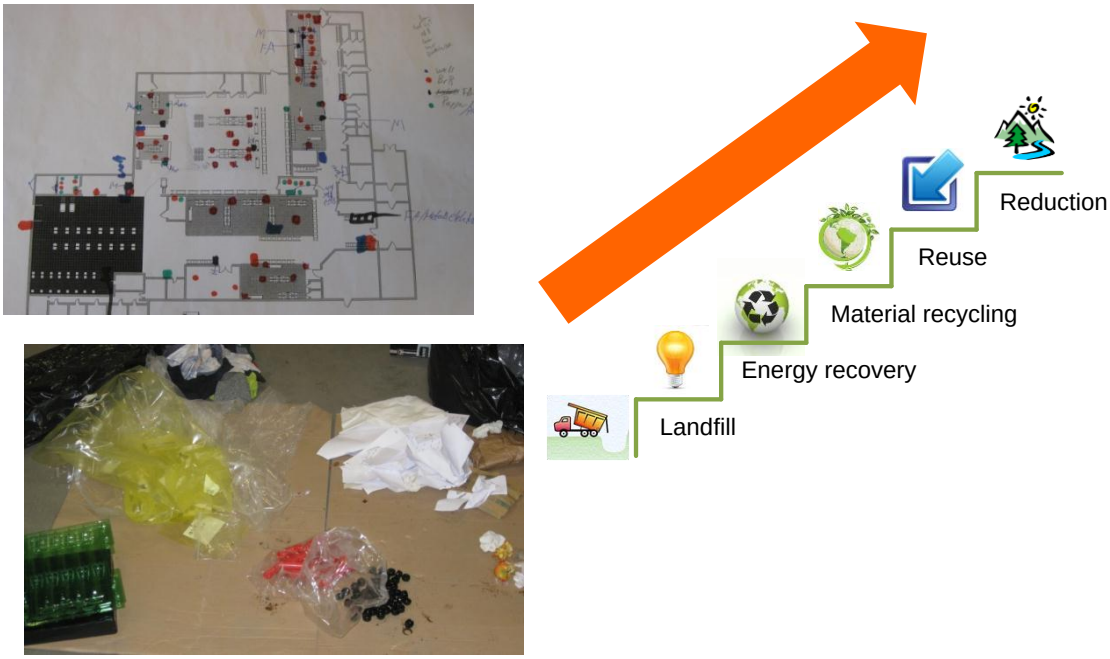


Figure 5. *The Waste Flow Mapping tool.*

The developed and implemented methods show great potential in supporting the environmental improvement work in production

5.1 Delivery to the FFI-goals

The GPS project with a funding from the FFI program of 2,75 MSEK over three years and a total budget of 6,1 MSEK including the co-funding of the participating companies, with the main part contributed in-kind from the FKG company Haldex, has resulted in a licentiate exam and thesis, about ten scientific publications, a handbook for industrial use, and contributed to the final part of a number of the education of graduate students by supervising them in thesis work related to the green production area. Besides the above mentioned, the following deliverables could be identified:

- The project has contributed to increased academic and industrial consciousness and positive mindset of the green dimension of the sustainability concept, applied in industrial production in manufacturing industry. This is an important start and pre-requisites for manufacturing companies in their process towards the overall vision of "the climate neutral factory".
- The project has contributed to concrete environmental improvement work in the production (at shop floor level) within the participating companies (and to some extent also at other actors outside of the project core team) through case studies, thesis work and method implementations. Emphasis has been put on activities that reduce the cost (a decision taken in the project, where the value adding approach is proposed to be

introduced as the next step when an industrial awareness and environmental maturity has been reached).

- A new consortium within the FFI manufacturing clusters has been created and an academic network has been formed within the area of green production.
- The production research within the FFI program has been strengthened by development and dissemination of new knowledge from the GPS project.
- The GPS project has included automotive manufacturers and OEM's, suppliers to the automotive industry (FKG members) and companies outside of the automotive business, implying that results have been disseminated in a broader context. The results from the project are in no ways specific to the automotive industry, but rather very generic, even suitable for other businesses than the manufacturing industry (e.g. process industry).
- The project has been clearly directed towards implementation;, new knowledge has been implemented in a number of industrial applications and a brief evaluation after the project ending shows a common and positive picture of the created methods, GPM and Waste Flow Mapping, considered to be practical and concrete tools that the companies intend to use further. In the end, the utilization of these research results implies that concrete environmental and energy efficiency improvements have been made in Swedish manufacturing industry which strengthens their competitiveness.
- The results from the project are presented in courses in the basic education at MDH.
- The GPS project has furthermore contributed to highlight a strategic perspective where the green aspect is included in the companies' existing Lean infrastructure, and contributed to integrate the environmental dimension as an aspect in some of the participating companies' system for implementing Lean production.
- The GPS project has put the finger on the necessity of driving the environmental improvement process/work from operations in order to get a real implication, and developed methods in order to broaden the engagement to include all employees. Knowledge has been disseminated via workshops, publications and by contributions in national and international conferences. In this way, the project has contributed to increased preconditions for a sustainable and competitive Swedish production.

6. Dissemination and publications

6.1 Knowledge and results dissemination

Besides dissemination of results during the GPS project time 2009-2012, we see the following potential of further dissemination:

- **By utilizing our co-production platform MITC**, Mälardalen Industrial Technology Center, for further education and implementation of environmental improvement methods, including distribution of the GPM handbook. MDH's business developer is

connected to the task, and has already supported to the development of a business model of this service oriented product.

- **By broader marketing of the methods**: For example, a seminar performed January 24 2013 at MDH within the MITC production seminar series presented the two methods GPM and Waste Flow Mapping to participants from both large companies and SME, who indicated interest for the methods. Also some of the project participants have indicated concrete interest of broader implementation of mainly the GPM method in their companies (one as part of their structure for lean production).
- **By coordination with other ongoing national projects**: For example; by our participation in the Lean and Green Production Navigator project, through Produktionslyftet, possibly also by inspiring the "Swedish Flagship project".
- **By continuing with a new GPS II project**: An application for FFI funding on "Design of Green Production Systems" has been made, and if the project application receives a positive decision, results from the GPS project will form the basis for further research and development within the area, still also utilizing and building on the excellent brand *Green Production Systems*.
- **By utilizing the potential for developing GPS courses on different level**: If resources/time is found, the potential for developing presentation material and documentation/reports to be used in education is extensive, for example could a course in "Green Production Development" be developed in modules of 3*2,5 hp, where modules could be selected and utilized for different purpose (for industry or undergraduates, or potentially even for PhD level).

6.2 Publications

Bellgran, M., Constructing responsibility, International Innovation, 2012

Bellgran, M., Höckerdal, K., Kurdve, M., Wiktorsson, M., GPM handbok, Mälardalens högskola 2012.

Höckerdal, K., Enhancing the process of environmental improvement in manufacturing industry, Licentiate thesis No. 154, Mälardalen University 2012.

Kurdve, M., Wendin, M., Bengtsson, C., Wiktorsson, M. "Waste Flow Mapping as a method to improve sustainability and waste management cost". *Greening of Industry Network*, GIN2012, Linköping, 22-24 Oct 2012.

Kurdve, M., Wiktorsson, M., Zackrisson, M., Harlin, U. "Incorporating Lean and Green integration into production system and business model – Experiences from Swedish industry", *Swedish Production Symposium*, SPS12, Linköping 2012.

Kurdve, M., Romvall, K., Bellgran, M., Torstensson, E. A systematic approach for identifying lean and green improvements related to packaging material in assembly´. *Swedish Production Symposium*, SPS11 Conference 4-5 maj 2011.

Kurdve, M., Hanarp, P., Chen, X., X Qiu, Zang, Y., Stahre, J., Laring, J. Use of environmental value stream mapping and environmental loss analysis in lean manufacturing work at Volvo. *Swedish Production Symposium*, SPS11 4-5 maj 2011.

Romvall, K., Wiktorsson, M., Bellgran, M., Competitiveness by integrating the green perspective: a review presenting challenges for research and industry, *20th International Conference on Flexible Automation & Intelligent Manufacturing* (FAIM2010) July 12-14, 2010 at California State University, East Bay.

Romvall, K., Kurdve M,, Bellgran, M., Wictorsson, J. Green Performance Map - An Industrial Tool for enhancing Environmental Improvements within a Production System´. *CIRP Life Cycle Engineering Conference*, 4-6 maj 2011.

Wiktorsson, M., "Drivers for life cycle perspectives in Product Realization" *Acta Technica Corviniensis – Bulletin of Engineering*, Volume 5. Fascicule 1 [January-March], pp81-86. 2012.

Wiktorsson, M., Bellgran, M., Jackson, M., Sustainable Manufacturing - Challenges and Possibilities for Research and Industry from a Swedish perspective, *the 41st CIRP Conference on Manufacturing Systems*, November, 2008.

Wiktorsson, M., Granlund, A., Bellgran, M., Reducing Environmental Impact from Manufacturing: Three Industrial Cases for the Manufacturing of Green Products, *42nd CIRP Conference on Manufacturing Systems*, Grenoble, France, June, 2009

Wiktorsson M., Granlund, A., Bellgran, M., "Reducing environmental impact from manufacturing – a multiple case study of the manufacturing of 'green' products" *Journal of Production Research & Management*, 1(3), pp17-32. 2011.

7. Conclusions and future research

The GPS project has been the starting point for the Division of Product Realization at Mälardalen University to combine production development and production system design with a sustainability perspective. Today, the project portfolio at the division comprises another handful research project within sustainable production. Broadly speaking, there is an evident growing interest among many production research groups in Europe to focus on the sustainability dimension. This unquestionably is the path for manufacturing research going forward.

8. Participating parties and contact person

The GPS project has dealt with a subject that has attracted a number of people from industry and academy. The actively participating companies have been; Haldex (Alfdex AB and Concentric Skånes Fagerhult AB), Volvo Technology, Volvo CE, Saab Automobile, All Emballage and ABB, and the two performing research groups within Mälardalen University are; Energy Systems, and Product Realisation. Besides, an expert and own consultant within the company Sustainable Business Mälardalen has participated and been a valuable coordinator towards activities in Eskilstuna community. Outside the core of the project, master students and environmental experts from different areas (including personnel from the Real Estate and facilities area) has participated

occasionally in case studies and in workshops. Another rather large number of companies and organisations have expressed interest for the project and the green production area. The project organization for management and performance of the work packages has comprised a research team, a steering and scientific reference group, regular workshops for experience exchange and a number of case studies performed at different companies (participating in the project, and outside).

The following participants have participated in the GPS project: Per Hanarp, Lena Moestam Ahlström, Birgitta Sjögren and Maria Walenius Henriksson, Volvo Technology. Mats Deleryd and Niklas Nillroth, Volvo CE. Martin Kurdve, Smurfit Kappa Sverige AB (later Swerea IVF and MDH). Sven-Arne Bertilsson and Emma Torstensson, Haldex Skånes Fagerhult (later Concentric AB). Monica Bellgran, Haldex AB (later MDH), Lars Schultz, Haldex Landskrona (later Alfdex AB) and Joacim Wictorsson, Haldex Brake Products AB, Landskrona. Jonas Esping and Pär Esping, All-Emballage. Magnus Johansson, Per Alfredsson and Lennart Malmsköld, Saab Automobile. Lennart Swanström and Linnea Petersson, ABB. Svante Sundquist, Eskilstuna/Sustainable Business Mälardalen. Erik Dahlquist, Eva Thorin, Magnus Wiktorsson, Karin Romvall/Höckerdal, Mälardalen University.

FORDONSSTRATEGISK
FORSKNING OCH INNOVATION

Adress: FFI/VINNOVA, 101 58 STOCKHOLM
Besöksadress: VINNOVA, Mäster Samuelsgatan 56, 101 58 STOCKHOLM
Telefon: 08 - 473 30 00