Public final report - FACECAR
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Projec leader: Dick O.Larsson

FACECAR

(Flexible Assembly for Considerable Environmental improvements of CARs)

Project within Sustainable production techniques

Dick O.Larsson

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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.**

For more information: www.vinnova.se/ffi

1. Executive summary

Project description
FACECAR is a strategic project for Swedish vehicle manufacturers. The overall purpose of the project is as follows:

- Adapt Swedish vehicle manufacturers' production processes to produce environmental friendly vehicles, thereby strengthen their competitiveness and endurance towards other competitors.
- Create conditions in production processes to promote a quick transition from conventional vehicles production to environmental friendly vehicles with new drive lines.

The focus for FACECAR on short term is to conceptualize the transition to a flexible assembly process and long term perspective to use a combination of existing and new production technologies.

Objective
The objective is to create sustainable (economical, society and environmental) and flexible assembly processes.
The project shall also create methods that support the assembly process due to increased information to the operator.
One specific objective will also be to review and sum up existing general safety requirements / regulations concerning handling of environmental fuels and energy batteries.

Result
The project has contributed to a quicker and cheaper readjustment to produce vehicles that meet future energy and environmental requirements. The projected has also given the Swedish vehicle industry a platform of knowledge for vehicle manufactures, sub suppliers and academics that has taken part of the introduction of more environmental drivelines. Flexible assembly ideas, methods, tools and theories has been identified, evaluated and developed for these specific conditions.

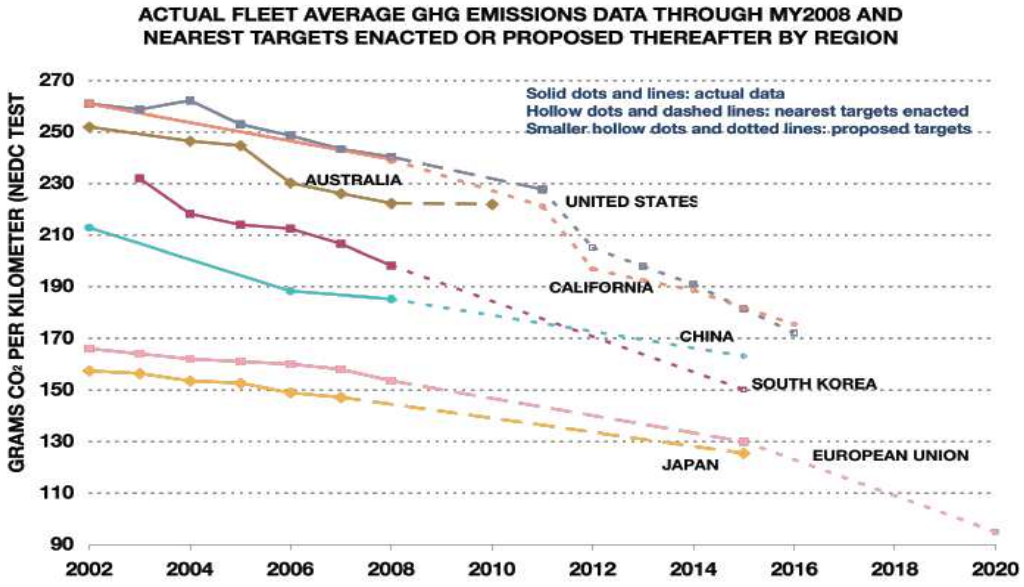
Specific result:

- Implementation of environmental drive lines in the production processes at the Volvo cars, AB Volvo and Saab Automobile.
- Promote and create cooperation and networks between Swedish vehicle manufacturers.
- Distribution of new trends and working methods from the vehicle industry to other manufacturer industries.

- The creation of safety instructions and education packages regarding the electrification of vehicles in high volume factories
- Scientific articles to support the growth/development of the Swedish vehicle industry.
- Popular science articles to help increase the public's environmental awareness connected to different kinds of drive lines on vehicles, with the hope to affect costumers to chose more environmental friendly alternatives in the choice of future products.

2. Background

In order to slow down the effects of global warming and reduce CO2 emissions, the transport sector has to produce more light-weighted vehicles with carbon neutral fuels in order to reduce the energy needs.



Source: VCC

The automotive industry has conceptualized different alternative clean vehicles, but due to uncertainties about new technology, high costs and an uncertain market, the vehicles have not been industrialized, with the exception of a few manufacturers. The first Hybrid Electric Vehicle (HEV), Toyota Prius, was mass produced in 1997 and introduced an interest in automotive industry to develop HEVs. Yet, 10 years later, new hybrids counted for less than 2% of sold vehicles. However, new hybrid and electrical driven vehicles are entering the market.

A variety of new technologies and fuels are currently of interest to become part of clean vehicles. Environmental friendly technologies need time to mature and in order to adjust to market and infrastructure the Swedish vehicle industry need to be able to produce vehicles with varying power train technologies and volumes.

Europe	US	China
		
Global Warming • Environmental protection • Climate change	**Energy Security** • Fuel availability • Delivery conditions	**Oil dependence / import** • Energy saving • Environmental protection • Trade balance / Inflation driver

Source: VCC

The challenge for Swedish vehicle manufacturers is that a variety of vehicles adapted to different markets, have to be produced in one or a few production lines.

In order to efficiently use existing and future production lines that accommodate conventional and environmental friendly models, a higher level of flexibility than they have today is required. FACECAR particularly focuses on challenges and consequences for the assembly line.
FACECAR is a strategic project for Swedish vehicle manufacturing industry, problematizing critical aspects of the realisation of environmental friendly vehicles (EFV) production. Currently, the main focus in EFV research and development has been on product design and development, where extensive improvements of EFV products have been conducted (e.g., C30BEV, BLIXT, Vattenfall V70PHEV). In order to industrially put EFV into practice in the same pace as they are developed, research into the *production process* of EFV is needed for development and improvements of existing knowledge and practice. Future research, such as FACECAR, need to get the grips with assembly line issues and its mutual impact on product development and evolution, production costs and investments, work environment and dynamic market demands, to avoid that manufacturing lags behind in the development and realization of EFVs.

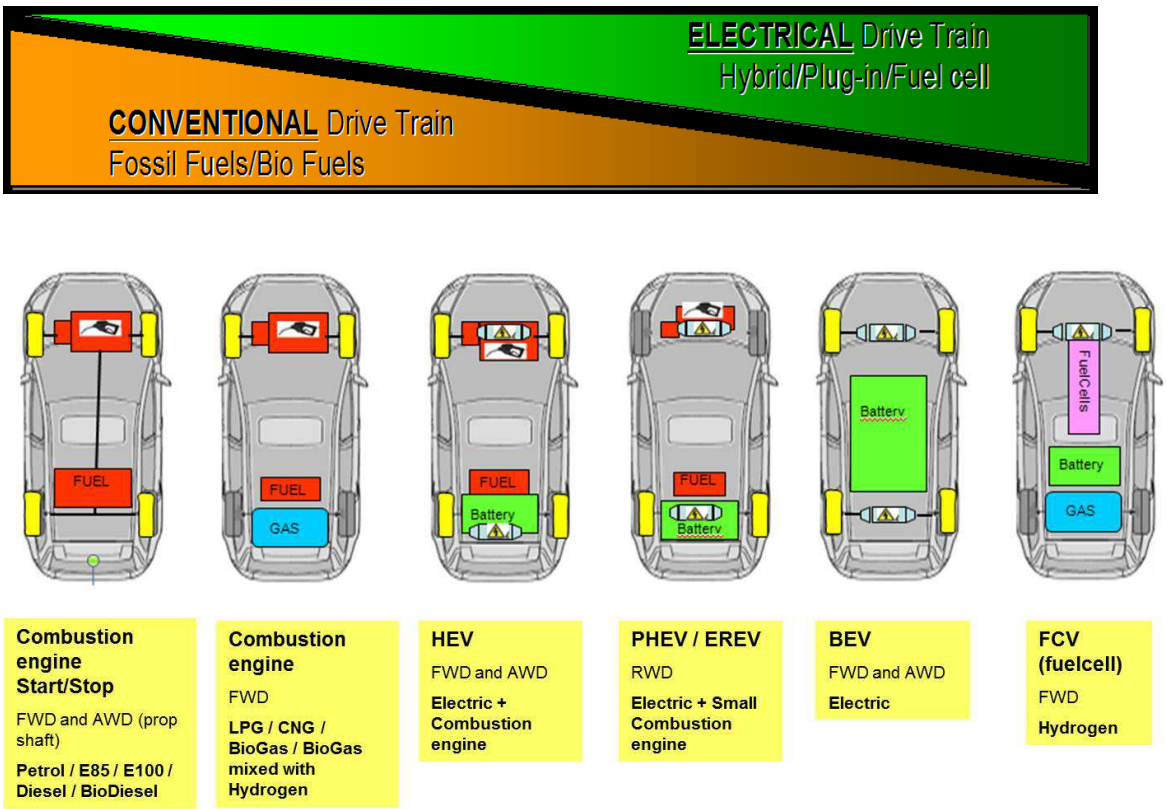
Environmental friendly technology and production challenges

Conventional power trains purely based on combustion engines will successively be replaced by technologies better fitted for a world with limited supply of hydrocarbon fuels. In a transition period, vehicles presume to contain conventional and new technologies as well as alternative fuels.

At least 100 different fuel cell concept vehicles have been designed up to now. During the last years weights and volumes have been dramatically reduced which has resulted in performance data close to traditional internal combustion engines (ICEs). Reliability has progressed dramatically, but needs improvement to be attractive on the market.

Theoretical calculations have shown that costs could be reasonable at high production volumes of vehicles with fuel cells. However, since market and technology does not yet allow it, mass production of fuel cell vehicles is not likely to be achieved during the next ten years. In the meantime production lines need to be able to handle a variety of vehicle models.

To Swedish vehicle manufacturers the prerequisites for integrating a variety of models is low cost, i.e., to integrate new models based on existing production lines and to a large extent use the same production equipment. In order to achieve this, there is a need for more knowledge about how a single production line can accommodate a wide range of power train principles and vehicle models. Figure 1 schematically shows the shift from conventional power train concepts to electrical powertrains.



The step from HEVs to PHEVs is a technological challenge. HEV batteries are designed for maximum power where the electrical drive works as a power booster in the vehicle. PHEV require a larger and more expensive battery which needs to be able to store electrical energy instead of power is a less mature technology. Future regulations regarding safe handling of new batteries and fuels in the production line are unclear**.**

3. Objective

FACECAR is a strategic project for Swedish vehicle manufacturers. The overall purpose of the project is as follows:

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4. Project realization

The project concludes seven work packages (WP) with connections to each other. Each WP has one leader that is responsible for the research and leads the development within each WP and its frame.
The content of each WP is as follows:

- WP 1 works with an analysis off the current and the ongoing situation within the industry and academic sector and will deliver data relevant to WP 2-6.
- WP 2 gives and overall strategy for flexible assembly.
- WP 3 works with the technical assembly process design.
- WP 4 works with the handling of information in manual assembly and processes.
- WP 5 works to achieve environmental laws and regulations and also training for new EFV systems.
- WP 6 is about the product – process and builds on the result from WP 1-5
- WP 7 coordinate and administering FACECAR in general.

The project has been at a big extent carried out by the help of a project portal where collective documents and workflows have been administrated and frequent web-meetings. This has significantly reduced the need of travelling, and hence lowered the

effects on the environment and also contributed to a greater transparency within the project and an increase of security in the flow of information. We've also achieved a strengthened the network between the project partners.

5. Results and deliverables

5.1 Delivery to FFI-goals

The projects obtained goal relative to goals of the FFI-Program Sustainable Production

The project has mainly addressed the following parts of the FFI-Program:

- *Flexibility in production and generation of solutions in variation of series production with the purpose of remarkably increase the processes' and the system's sustainability (from a ecological and economical perspective)*
- *The producing of a vehicle with conventional and new drive lines, taking place in the same production system.*
- *Substantially contribute to achieving the following goals within production preparation and production:*
    - *30% higher productivity in the production processes.*
    - *40% higher productivity in the production preparation.*

The project's vehicle manufacturers has develop their existing production processes for traditional vehicles to include the production of environmental friendly vehicles, and with this created future production strategies that increases their strength towards other competitors.
With the production strategy of the future the flexibility for new drive lines increases and minimizes the need of investment to the production process.

Industrial partners Volvo Cars are expected to achieve program goals above if you compare first generation PHEV 2012 in the existing architecture and the second generation PHEV2015 in the newly developed architecture. The optimization of the production process has been created by affecting the production to adapt to the existing production process and to create a future sustainable modularization of the products. Furthermore, this implies that we also create a simplified preparation process for these future products. Ideas of change that has been created in the FACECAR-project has for the greater part been implemented in Volvo Car's production process.

Industrial Partners AB Volvo has during the duration of the project further worked with the development and production of alternative drive lines. The project has contributed with important knowledge regarding law requirements and risk analysis for productions of electric hybrid- and gas vehicles. The aspects of safety have taken a central part since these vehicles are produced in the same production flow as conventional drive lines. This

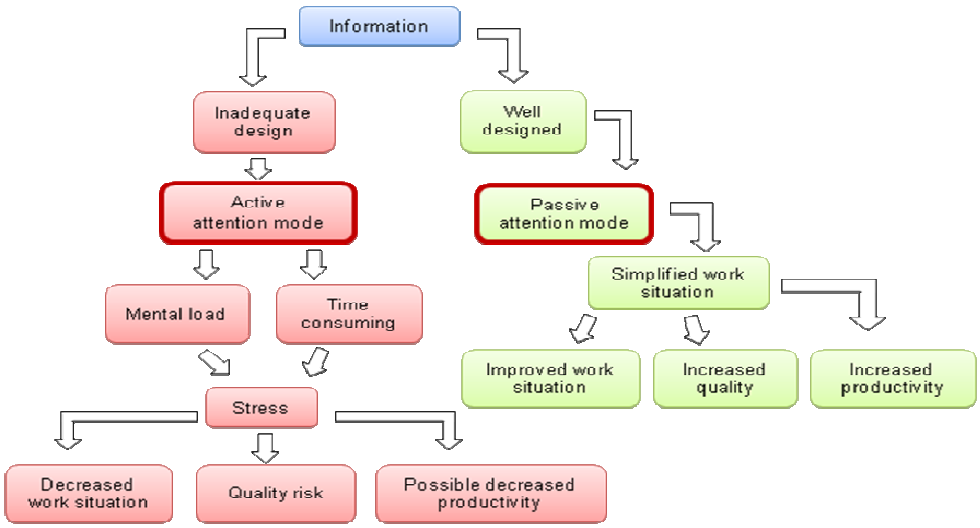
puts demands on thoughtful strategies when it comes to education organization and responsibilities as well as technical solutions.

SP (Technical Research Institute of Sweden) has taken part in creating a network within the Swedish vehicle industry with respect to safety in production and handling of vehicles electrified drive lines, which will meet annually. SP has also prepared a number of publications regarding security and the demands of education that has came to great use in the development and revision of internal education programs and safety procedures within companies.

The Participating academies HiS(University of Skövde) and LiU(Linköpings University)
Has contributed to the following goals within the program:

- *The possibilities for the Industry to conduct competitive knowledge based production in Sweden.*
- *Take part in a continued competitive vehicle industry in Sweden.*
- *Strengthen the research on certain prioritized research areas in production techniques and also support research and innovation fields.*
- *Work to find new knowledge and implement it and also implement existing knowledge in industrial applications.*

By creating and developing a model where, among other things the flow of information described below (For more information se Brolin et al., 2011, *Inadequate presented information and its effect on the cognitive workload*) the scientist has contributed to the flow of information between the operator and the system, and its effect on productivity and quality, in a better way can be considered in future production system development within Swedish vehicle industry.

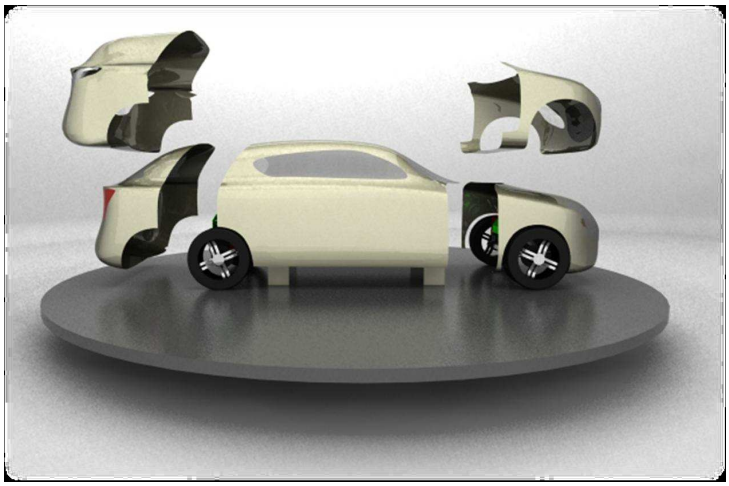


Furthermore, the research has contributed to clarify the relationship between the terms architecture – platform – vehicle and how you could handle these in a future production line adapted for *mixed model assembly*, which also facilitates the production in Sweden.

By modularizing future cars with the new drive lines in a structured manner, they can be produced under the same *Bill of Process* (BOP) and in that way can the vehicle industry make us of its existing investments in production equipment where it fits and do targeted investments towards the right assembly points.

Both of the academic partners has thru their participation in the project been strengthen within their respective field of research; HiS within the shaping of assembly instructions and the configuration of work places connected to information carriers modelled for the operators, LiU within the shaping of production systems and the connection to automatizing and connection between the products and the production systems shape. Furthermore, the project has strengthened its cooperation between the vehicle industry and government agencies, universities and research institutes.

The Project has generated a lot of new knowledge that the academics has further developed to different course objectives in different education programs on bachelor degree level and master's degree level. This has contributed to increase the quality of the production technique education in such a way that the students are more prepared on the conditions of the vehicle industry. The project has, thru this work, developed a conceptual idea for the vehicles of the future that builds on all the contributions form the WP's and the view of vehicles of the next generation of customers.



An overview of a future concept car that is modularly designed to be adaptable in a production cycle on the varying demands of the costumers. The concept of this is to produce the modular cars of the future and create a car that encumbers the environment less, while it has fitted weight, volume and drive line based on the demands of the costumer, eg a small battery driven car for transport to and from work within the city limits and more sustained drive line and bigger package volume when the family is going for vacation.

6. Dissemination and publications

6.1 Knowledge and results dissemination

WP2/3/4/5/6 has spread their knowledge about its results thru half-day seminars at three occasions during 201/2012: two seminars at Volvo Cars and one at AB Volvo. All of these seminars have been appreciated and drawn a big crowd ranging between 25-80 visitors. These events have also been a great opportunity to create networks within the Vehicle industry.

6.2 Publications

Achieved academic results and other reports

- Brolin, A, Bäckstrand, G., Thorvald, P., Högberg, D., Case, K. (2012). *Kitting as an information source in manual assembly*. Paper submitted to the 4th International Conference of Applied Human Factor and Ergonomics (AHFE), San Francisco, USA, July 2012.
- Hanson, R., Brolin, A. (2012). A comparison of kitting and continuous supply in in-plant materials supply. *International Journal of Production Research.* DOI:10.1080/00207543.2012.657806. Available online: 22 Feb 2012.

- Brolin, A., Bäckstrand, G., Högberg, D., Case, K. (2011). *Inadequate presented information and its effect on the cognitive workload*. Proceedings of the 28th International Manufacturing Conference (IMC 28), Dublin, Ireland, August 2011.
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- Brolin, A., Bäckstrand, G., Högberg, D., Case, K. (2011). *The use of kitting to ease assemblers' cognitive workload.* Proceedings of the 43rd annual Nordic Ergonomics Society Conference, Oulu, Finland, September 2011, ISBN 978-951-42-9541-6.
- Hanson, R., Brolin, A. (2011). *A comparison of kitting and continuous supply in in-plant materials supply*. Proceedings of the Swedish Production Symposium (SPS), Sweden, Lund, May, 2011.
- Bäckstrand, G., Brolin, A., Högberg, D., Case, K. (2010). *Supporting Attention in Manual Assembly and its Influence on Quality*. Proceedings of the 3rd International Conference of Applied Human Factors and Ergonomics (AHFE) 2010, Karwowski, W. and Salvendy, G. (Eds.), USA, July 2010, ISBN 978-0-9796435-4-5.
- Diffner, B., Björkman, M., Johansen, K. (2011). *Successful Automotive Platform Strategy – Key Factors*. Proceedings of the Swedish Production Symposium (SPS), Sweden, Lund, May, 2011.
- Diffner, B., Björkman, M., Johansen, K. (2011). *To stay competitive in future automotive assembly – Some challenges related to flexibility*. Proceedings of the 2011 International Conference on Industrial Engineering and Operations Management Kuala Lumpur, Malaysia, January 22 – 24, 2011
- Diffner, B. (2011). *Combining Flexibility and Efficiency in Automotive Assembly*, Licentiate Thesis No.1501, LiU-TEK-LIC-2011:40, Linköping.
- Diffner, B., Björkman, M., Johansen, K. (2011). *Manufacturing Challenges Associated With the Introduction of New Powertrain Vehicles*, 21st International Conference on Production Research (ICPR21), 31st of July – 4th of August, Stuttgart, Germany
- Weiner, A. (2011). Modulindelning av bil – metod för att möta framtida krav på kundanpassning och flexibilitet, Kandidatrapport, Linköping
- Häggström, E., Ramnell, G., Gustafsson, M., Jansson, R. (2010). Utvärdering av palettsystemet för Volvo C30 PEV, Internrapport FACECAR (konfidentiell)
- Olsson, A. & Saarela, T. (20xx). Virtuell demo på framtidens bilfabrik, Kandidatarbete, Göteborg
- Olsson, M. (2011). Förslag på möjlig standardisering för fastsättning av batteri för hybrid- och elbilar, Kandidatrapport, Linköping
- Sundqvist, J. (2011). Konceptutveckling av el- och hybriddrivlina för flexibel montering, Kandidatrapport, Linköping
- eFlexiCar. (2011). Projektrapport eFlexiCar, Sammanfattande resultat av 6 kandidatrapporter inom projektet, Linköping
- Hedberg, K. (2011). Att främja kreativitet i ett produktutvecklingsprojekt, Kandidatrapport, Linköping.
- Norman, B. (2011). Storytelling i produktutveckling – en marknadsundersökning för funktionsförsäljning på bilmarknaden, Kandidatrapport, Linköping.
- Svensson, M., & Sundkvist, M. (2011). Utvärdering av en potentiell övergång från traditionell produktförsäljning till funktionsförsäljning inom bilbranschen, Kandidatrapport, Linköping.
- SP-rapport 2010:55 utfärdad 2010-09-15: Nuvarande lagkrav för montering av elfordon samt elhybridfordon (EV/HEV) i Sverige.
- SP-rapport 2010:56 utfärdad 2010-09-15: Riktlinjer för differentierad utbildning av personal vid montering av elfordon samt hybridfordon (EV/HEV).
- SP-rapport 2010:63 utfärdad 2011-04-15: Nuvarande lagkrav för montering av fordon drivna av trycksatt gas.
- SP-rapport 2012:09 utfärdad 2012-02-17: Generisk process för produktion av framtidens fordon med avseende på framtida krav och föreskrifter.

7. Conclusions and future research

Effects from the project

Cross-functional knowledge about joint guidelines for safety, education etc.:

- for WP5, a group has formed within the vehicle industry that has annual gatherings to create and maintain a collective basis within electric safety/education and a common definition of groups within production, in order to create and precede any legislations in the future, also give guidelines for legislative changes, in order to create a good economic competitiveness within the Swedish vehicle industry.

Management accounting:

- We have within WP7, with help of a well developed discipline for reports, forecasting and simple graphic visual methods, developed the traditional financial reporting to work as real management accounting. Thus, we have been able to reprioritize and rearrange between the different activities with full control over the costs.

Future production processes for future drive lines and existing drivelines:

- The creation of a new future BOP within respective vehicle partner, which can handle the new situation on a sustainable economical plane.

For Volvo Cars Manufacturing's strategic hybridization and electrification portfolio for the closest future, has this FFI project 'FACECAR' been significant to understand and clarify what processes/process related problems that has to be accounted for, reflected in the individual WPs. This is very valuable in a big paradigm shift between old and new drive line development, where we in manufacturing must take important strategic decisions that has a major impact on the future.

Innovatum AB have within the frames of the project FACECAR developed and refined tools for the management accounting of the project that can be used as general means of aid and can now be applied on many more projects in our portfolio. Beyond this, the networks and the interaction forms in FACECAR of big importance for the development of our role as a facilitator and project leader.

AB Volvo has thru the FACECAR gained an understanding for the challenges the future drive lines will have on our production processes. This project has given us a clear contribution when it comes to security aspects when handling these new drive lines.

SP Technical Research Institute of Sweden has thru its participation in the FACECAR project enhanced its competence within "Battery and Hybrid system" with knowledge and experience of the new risks in security that is generated in the handling of electric and electric hybrid vehicles in the vehicle factories. The close collaboration between vehicle manufacturers taking part of the project has given SP and extended understanding of the problems and needs for the handling of the new propellant in the production systems that are to be implemented. This applies to both electric vehicles, gas driven vehicles and vehicles to be propelled with new liquid fuel.

Suggestions for further research and projects:

- Increased production knowledge about components with high voltages(100V-1000V) that exists in an electrified vehicle, to later be able to compete with today's suppliers outside of the European Union.
- Light-weight material's effect in assembly factories, building of knowledge of different methods for assembling of traditional body components that now are moved to the assembly factory.
- A new challenge that consists of handling these light-weight components in the assembly process to a cost-effective way with high product quality in big volumes.
- Machine/Human in the future assembly process; building of knowledge to make the operators assembly work more effective for the human and production system in a positive way.
- A challenge would be to in a more effective way be able to use the workforce and in such a way that it lowers the production costs. The demands on high flexibility within the vehicle industry make a higher grade of automatizing more difficult, especially in the assembly that requires very high workforce intensity. There are great potentials in letting the machines be a "helper" in the assembly operations. This however, happens on the human's terms, the human is the one in charge in the assembly processes.
- The increasingly complex assembly environment demands a continued research where the focus is to evaluate the cognitive aspects that affects the quality and productivity, and how this can be evaluated in earlier developing phases.
- The safety while working with electrical vehicles and electrical hybrid vehicles. The development of technology advance at a quick pace which leads to an increased complexity and difficulties to fully understand the safety risks during the assembly and handling of these vehicles.
- Actively promote for the development of a common regulatory framework for electrical vehicles and electrical hybrid vehicles.
- Continued research with focus on the internal material flows and how these could work in the best way to support the central flow of information that is demanded in a more complex production environment.

8. Participating parties and contact person

SP – Sveriges Tekniska Forskningsinstitut
Contact: Thomas Berg, thomas.berg@sp.se

AB Volvo
Contact: Lena Moestam Ahlström, lena.moestam.ahlstrom@volvo.com

Volvo Car Corporation
Contact: Dick O.Larsson, dlarso3@volvocars.com

Saab Automobile AB

Linköpings Universitet
Contact: Mats Björkman, mats.bjorkman@liu.se

Högskolan i Skövde
Contact: Gunnar Bäckstrand, gunnar.backstrand@his.se

JMAC Scandinavia
Contact: Lars Wenström, wenstrom@jmac.se

Innovatum AB
Contact: Lars Anger, lars.anger@innovatum.se

DELFOi
Contact: Henrik Kihlman, henrik.kihlman@delfoi.com

ETC Battery and FuelCells Sweden AB
Contact: Stefan Olsson, stefan.olsson@etcab.se

FORDONSSTRATEGISK
FORSKNING OCH INNOVATION

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