Centre for ECO$^2$ Vehicle Design

Operating Plan
Phase II:
23/2 2008 – 22/2 2011
Centre Objectives and Long-term Strategic Plan

The Centre focuses on research within Vehicle Design to achieve more environmentally friendly and economically competitive rail and road vehicles.

The long term vision of the Centre for ECO² Vehicle Design is:

By the year 2016 a world-class research centre has been established, focusing on technical solutions leading to improved performance, reliability and safety; with a reduced impact on the environment, enabling a balanced system cost and maintaining comfort in rail and road vehicles. Within the Centre, vehicle design is a holistic process encompassing the involved individuals, technical solutions as well as generated methods.

The overall objectives of the Centre are:

Within rail and road Vehicle Design perform research, addressing ECOonomical and ECOlogical – ECO² – aspects to save material and energy resources, and reduce emissions, through vehicle research in the areas of structural mechanics, noise and vibration, vehicle dynamics, and aerodynamics, with respect to lifecycle cost, passenger and driver comfort, energy consumption, material selection, handling qualities, functionality, safety, reliability and other customer added values.

The underlying strategy is:

• To formulate vehicle-class dependent design criteria, initiate research activities focused on multidisciplinary and multi-vehicle research in order to develop and demonstrate new technologies, the required design tools and their integration, see Figure 1.
• To identify and launch lasting joint research activities aiming to resolve the conflict of compatibility between different demands on functional requirements and ECO² objectives.
• To introduce optimisation as a design paradigm, concurrently addressing ECO² design criteria, in a conceptual design environment, for a wide range of vehicle systems.
The challenge to develop competitive and more environmentally friendly rail and road vehicles is to deliver material and energy efficient vehicles with low emissions while also meeting individual and societal demands for mobility, vehicle performance and reduction of greenhouse gases. The relation between legal requirements, customer demands and the transportation task constitutes a highly complex design space for any given type of vehicle. When the development is characterised by a strong focus on technical innovations and utilization of technical solutions, design, configuration and styling, production methods and manufacturing systems, as well as customer added values, the ECOnomical dimension is important. Also, the increasing concern with environmental and societal issues forces a new dimension related to the impact on health and quality of life as well as the environment, i.e. the ECOlogical dimension of the design space. The demands for sustainable development through customer awareness, product competition and environmental regulations are challenging the vehicle industry to produce quieter, more comfortable, efficient, and at the same time more lightweight vehicles. But, reducing the weight of a vehicle, while maintaining the structural integrity, often leads to drawbacks such as increasing noise and vibrations. In order to realize a breakthrough in sustainable development, one important aspect for the transportation industry together with the research community, is thus to consider vehicle design for a wide range of vehicle systems concurrently addressing ECOnomical and ECOlogical (ECO²) vehicle design criteria. The Centre for ECO² Vehicle Design that started in February 2006 has taken on this challenge.

1.1 General Goals
Transportation is a key area in the worldwide efforts to combat the now widely accepted climate change. The need for sustainable development calls for dramatic changes in transportation and vehicle designs. One general goal for the Centre is to contribute to this transition.

The multidisciplinary and multi-vehicle character of the Centre is a new approach towards fruitful ECO² results and, along with the close cooperation with the vehicle industry and authorities, the relevance is guaranteed. This new way of thinking should reinforce the interaction between different modes of transportation and support ideas on new innovative designs of vehicles as well as vehicle components.
The international dimension of the Centre will be strengthened, further exploring the international contacts and activities carried out by the partners of the Centre. This exchange will make sure that the Centre activities are well positioned in a worldwide context and that the label “Centre of Excellence” really applies to our Centre.

For the three-year activity period ahead, the Centre activity volume will increase to “steady-state” and involve more personnel. Additional research areas will be introduced, still keeping a critical mass in the different areas selected. Also education and training will be better linked to the Centre research.

1.2 Specific Goals for the Centre for ECO² Vehicle Design

Two overall goals for the Centre are:

- To create a world-class research Centre involving the vehicle manufacturing industry chain from system to component level, transportation industry, government agencies and authorities and excellent research groups.
- To contribute to increased competitiveness for the Swedish vehicle industry through the provision of a new generation of engineers and researchers, all sharing a holistic perspective on the vehicle design process from a sustainable development point of view.

In the Centre activities on rail and road vehicle design, the main goal is to achieve improvements in EConomical and ECOlogical performance of the vehicles. A life-cycle perspective is adopted in this process including the phases of vehicle manufacturing, operation and re-cycling. At the same time issues like reliability, safety and comfort must not be violated.

A number of ECO² indicators are currently being defined to evaluate the ECO² impact of proposed vehicle designs. This work is ongoing within the project Virtual Vehicles. Examples of possible ECO² indicators for the vehicle operational phase can be found in section 4.

The project Virtual Vehicles will also support this process by the definition of Reference Vehicles so that improvements in the ECO² indicators can be measured, for instance in percent. In addition, the Virtual Vehicles project should support ongoing and new projects with information on, for instance, how much a kilogramme weight reduction of the defined vehicles is worth with respect to energy and CO₂ levels. In this way the most ECO² efficient types of design modifications can be pin-pointed.

Further goals for the Centre are also:

- ECO² compatible innovative solutions
- Conceptual design tools, guidelines and tutorials for derivation of recommended design practice
- Skilled engineers and scientists, trained in ECO² vehicle design
- Qualification of various approaches, showing application range, limits and possibilities for ECO² vehicle design
- Documented set of generic models, data and results, which can be used in training, teaching and general project dissemination
- Gained experience on working in multidisciplinary and multi-vehicle projects.
- Systems Engineering experience
- A set of conference and journal publications describing the research results and making these accessible to the wider scientific and engineering community
- A number of MSc, Licentiate and PhD theses
- Host a number of seminars, workshops and conferences
• Relevant communication of Centre results to other research groups and the community

2 Centre Partners

The participating partners forming the core of the Centre for ECO² Vehicle Design include most of the major Swedish vehicle manufacturing industry along with transport authorities, public services and small companies with a link to vehicle design. Their respective background and interests in the Centre are briefly summarised below.

Bombardier Transportation AB

Bombardier Transportation offers a full range of rail vehicles for urban and mainline operation as well as modernization of rolling stock and operations and maintenance services. Bombardier Transportation in Sweden is employing some 1300 people at its sites in Västerås and Stockholm. Bombardier Transportation believes that a close relationship with universities in Sweden is very important to sustain the level of expertise knowledge in the company. The research scope in the Centre for ECO² Vehicle Design is considered to be of high priority for its future competitiveness, as well as for the Swedish vehicle industry as a whole. Combining economical and ecological design in a multidisciplinary research program with involvement from industry, government authorities and academia, gives a strategically interesting project scope that has the potential of changing the way vehicles are built in the future.

SAAB Automobile AB

Saab is marketing and selling cars in more than 60 countries worldwide. The most important markets are: USA, United Kingdom, Sweden, Germany, Switzerland, Italy, Australia, France, The Netherlands and Norway. International and Diplomat sales, IDS, accounts for considerable volume and could well be seen as one of the top markets. 4733 people were employed by SAAB Automobile AB at the end of 2006. We consider the research scope of the Centre to be an area of high priority for our future competitiveness, as well as for the Swedish vehicle industry as a whole. Combining economical and ecological design in a multidisciplinary, systems oriented, research program with involvement from industry, government agencies and academia, covering a range of transportation vehicles, gives a strategically interesting project scope that has the potential of changing the way vehicles are built in the future.

SCANIA CV AB

Scania is one of the world’s leading manufacturers of trucks and buses for heavy transport applications, and of industrial and marine engines. With 32 000 employees and production facilities in Europe and Latin America, Scania is one of the most profitable companies in its sector. During 2006, net sales totalled SEK 70,738 billion and income before taxes amounted to SEK 8,583 billion. Scania products are marketed in about 100 countries. We consider that the Centre and its research scope is an area of high priority for Scania. The main reasons to why we participate are:

• The Centre will contribute to our strategic recruitment for skilled engineers as well as for researchers with doctoral degree.

• Common research projects will deliver valuable results and knowledge into our product development.

• The Centre will be a catalyst to mutually develop competence and transfer knowledge from Scania to KTH and vice versa.

• Competent engineers and researchers is one of the most important factors for Scania’s future competitiveness, as well as for the Swedish vehicle industry.
**VOLVO Construction Equipment**

Volvo Construction Equipment Sweden (Volvo CE) consists of: Hauler and Loader division (Former Volvo Wheel Loaders and Volvo Articulated Haulers), Component division and Cabs division. Hauler and Loader division develop and manufacture wheel loaders and articulated haulers. Approximately 4,700 Volvo CE employees are involved in the hauler and/or loader business in Sweden. On a global level, the number of employees is more than 10,000. Volvo CE’s main interests in the Centre for ECO² Vehicle Design are development of competence and methods related to optimization of vehicle operability, productivity and light-weight structures.

**VOLVO 3P**

Volvo 3P is a Business Unit within the Volvo Group. It combines the resources of the four truck companies in the areas of Product Development, Product Planning, Purchasing and Product Range Management. Volvo 3P works in partnership with the four truck companies (Mack, Renault, Nissan and Volvo) to ensure a powerful and strong competitive offer for each brand. It offers its customers innovative and customized solutions that make optimum use of the size, volumes and resources of the four truck companies while at the same time preserving the unique distinction and characteristics of each brand. The organization has a global presence with the majority of the 3,800 employees located in Göteborg, Lyon, Greensboro, Allentown, Ageo and Bangalore. The Volvo 3P interest in the Centre for ECO² Vehicle Design is focused on vehicle and infrastructure concepts and supporting technologies that optimize the environmental and transport efficiency aspects of future transport solutions.

**A2Zound by Semcon**

A2Zound by Semcon (A2Z) is a company of 30 employees, located in Linköping. The core business of A2Z is the development of new technology for improving noise and vibration comfort in vehicles. Of special interest are adaptive noise and vibration control systems. The customers include major aerospace and automotive manufacturers. In the Centre for ECO² Vehicle Design A2Z is interested in research activities for NVH (Noise Vibration and Harshness), and in particular for CAE modelling and adaptive systems for controlling road noise.

**VTI**

The Swedish National Road and Transport Research Institute (VTI) is a national research institute that performs advanced applied research and development of high quality. The research shall contribute to enhancing knowledge and skills within the transport sector aiming to fulfilment of the six sub-goals of the national transport policy objective: an accessible transport system, high transport quality, safe transport, a sound environment, favourable regional development and gender equality. Our positive attitude to the Centre for ECO² Vehicle Design includes our full endorsement with regard to the need for a Centre of Excellence on this subject and the possibilities to establish a competent and world-class research centre in accordance with the presented plan. We believe that this would be useful and profitable for the Swedish vehicle, tyre and road industries as well as it promises to provide an improved environment for society.

**Banverket**

Banverket (The Swedish Rail Administration) is the national authority responsible for the rail sector in Sweden. This means that Banverket follows and conducts development in the railway sector, assists the Swedish Parliament and Government on railway issues, is responsible for the operation and management of the state-owned rail infrastructure, co-ordinates the local, regional and inter-regional railway services, and provides support for research and development in the rail sector.
Vägverket

Vägverket (The Swedish Road Administration) is the national authority assigned the overall responsibility for the entire road transport system. Vägverket’s task is to co-operate with others to develop an efficient road transport system in the direction stipulated by the Swedish Government and Parliament. Vägverket has been commissioned to create a safe, environmentally sound and gender-equal road transport system that contributes to regional development and offers individuals and the business community easy accessibility and high transport quality.

KTH

KTH, The Royal Institute of Technology in Stockholm, Sweden is responsible for one-third of Sweden’s capacity of engineering studies and technical research. The university has more than 12,000 undergraduate students (including over 2500 international students), 1,500 active Ph.D. students and a staff of 3,100. KTH has extensive and internationally renowned research covering most areas within engineering and science. It participates in 95 projects in EU 6th framework programmes comprising a total grant of 35 million Euros. KTH has a long tradition of collaboration with the vehicle industry. The Department KTH Aeronautical and Vehicle Engineering is unique in its coverage of all vehicle engineering disciplines, i.e. air, ground, rail and sea transport vehicles. The high level of research on theoretical aspects is validated through the extensive experimental resources held by the department, as well as field tests in close cooperation with industry partners. The academic staff is active in research and teaching in a wide range of application-focused research, some examples being: computation based aerodynamic design; performance and manoeuvrability of aircraft, cars, trucks etc.; noise and vibration in machinery and transportation; lightweight load carrying structures; mechanics, motion and structural loads on high speed vessels; rail vehicles and their dynamic interaction with the track, railway system efficiency; modelling, energy consumption and efficiency and simulation of nonlinear engineering dynamics. KTH Optimization and Systems Theory is associated with the Centre, but has not yet taken an active part in the research activities, something which is anticipated to start during Phase II. The research group Environmental Strategies Research – fms at the department KTH Urban Planning and Environment, has a pronounced interdisciplinary profile, and consists of engineers, economists, ethnologists, sociologists and experts in natural science. The main engagement is in comprehensive future studies and in development of analytical tools for sustainable development. The research focus is on what a sustainable city might look like, and to explore methods for the assessment of environmental impacts of various systems.

3 Centre Management and Organization

3.1 Leadership structure and collaboration

The Centre is managed by the Director and the Assistant Management Group, AMG. The Centre Coordination Group, CCG, consisting of representatives of the external partners and from KTH, is responsible for the continuous work with formulating and managing research projects within the Centre. The Board consists of representatives from the external partners, as well as KTH representatives.

During Phase I, a successful effort was made to establish an efficient and working organization. Having this in place, Phase II efforts will be to consolidate and, when needed, develop the leadership and management model. In particular, we will continue to improve the effectiveness of the management work. The organizational structure also alleviates the communication at multiple levels between the Centre and the external partners as well as the communication within partners, see Figure 2.
3.2 Director and AMG

One of the novel ideas within the Centre for ECO\textsuperscript{2} Vehicle Design is a decentralized leadership. The Assistant Management Group (AMG) is responsible for managing the everyday activities of the Centre. This provides a robust management function and stimulates the multidisciplinary discussions and interactions within the Centre.

The Director of the Centre is Professor Annika Stensson Trigell. The responsibility of the AMG is the everyday administration of the Centre, i.e., reporting, industry contacts, handling of project ideas and organizing common meetings.

The AMG consists of the following researchers at KTH Aeronautical and Vehicle Engineering:

- Prof. Mats Berg, Railway technology
- Dr. Susann Boij, Sound and vibrations
- Dr. Gunilla Efraimsson, Aerodynamics
- Dr. Jenny Jerrelind, Vehicle dynamics
- Dr. Per Wennhage, Lightweight structures

Areas of responsibility are, as of December 2007, Assistant director, Idea process, Virtual standard, Finance/Status and Image & communication/Education, see Figure 3. The responsible areas are rotated annually to facilitate a high level of redundancy.
3.3 CCG

To stimulate the creation of (r)evolutionary ideas and to fulfil the role as a communicating link between the Centre activities and the respective partners of the consortium, the Centre Coordination Group (CCG) was established already at the start of the Centre. The group consists of partner representatives, one representative from KTH Environmental strategies research, the Director, the members of the AMG and the vice chairman. The CCG have meetings four times per year, but also participate in other Centre activities such as seminars and hearings. The CCG is responsible for developing and evaluating new project ideas, by discussions within the CCG and as representatives carry on the discussion with colleagues at the respective partner. For ongoing research projects, the CCG continues to develop and extend the projects as appropriate for the Centre goals. The ECO$^2$ aspects are under the responsibility of the CCG through dedicated Technology Monitors (TM) and ECO$^2$ Monitors (EM), representatives from the industrial partners for the different Virtual Vehicles (Truck, Car, Train and Construction Equipment). In the work and projects on the Virtual Vehicles, the CCG thus acts as a reference group.

3.4 Board

The Board of the Centre consists of representatives from the main industrial and governmental partners as well as from KTH. The board typically meets three times per year. Its task is to determine and monitor the activities of the Centre. The Board determines the activities within the Centre. The Board shall work for the common interests of the Partners.

Tasks of the Board are:

- to approve research projects, following the suggestions from CCG, the intent of the Operational plan and the main contract
- inform the Partners if conditions occur that essentially delays or prevent the realization of the Operational plan
- submit a yearly budget to the Partners
- supervise that yearly reports and final reports are submitted by KTH
3.5 **Steering Committee**
Each project is managed by a *Steering Committee* (SC), consisting of a project leader, industry representatives and, if relevant, the supervisor of involved PhD students or other KTH representatives.

3.6 **International Advisory Board**
The role and function of an international advisory board has become clearer as the first phase of the Centre is coming to an end. Thus, the need to initiate the international advisory board is now more urgent. The scanning of possible candidates has commenced, and the international advisory board will be defined early during Phase II along with the appropriate guidelines and other documentation. The international advisory board should consist of international specialists and generalists, and should be consulted every 2 years or more frequently if required. Their primary role should be to advise on research directions and the scientific content of the Centre activities.

3.7 **Plan for equality of opportunities**
The Centre for ECO² Vehicle Design is part of a university organisation where questions of equality with respect to gender and ethnicity, are constantly on the agenda. Efforts to ensure equality of opportunities of everyone connected to KTH activities are being made at university level as well as lower levels in the organisation. The Centre complies with the plans for equality “Jämställdhets- mängfäls- och likabehandlingsplan” established and maintained by the KTH School of Engineering Sciences.

3.8 **The Centre in the University Organisation**
The Centre is organised within the department KTH Aeronautical and Vehicle Engineering (AVE) with participation from the department KTH Urban Planning and Environment and KTH Optimization and Systems Theory. On the Board, AVE is represented by its chairman, and KTH by 3 representatives. KTH also contributes to the funding of the Centre, as part of the intention to encourage the establishment and management of competence centres.

3.9 **Communication Plan**

**Internal communication**
The objective is to establish and maintain a network between people involved in the Centre to keep all informed what is going on. This is achieved by:

- Meetings (AMG-meetings, CCG-meetings, Board meetings, Steering committee meetings, project meetings)
- One yearly whole day seminar – the Spring seminar – where all active research projects within the Centre are presented and discussed
- One yearly public whole day seminar – the Autumn seminar – on a topic relevant for the Centre
- A homepage with login functionality giving access to for example more detailed project documentation than available without login.
- Mailing list to facilitate communication within certain groups; amg@eco2vehiclekth.se, cgg@eco2vehiclekth.se, board@eco2vehiclekth.se, phd@eco2vehiclekth.se
- Project newsletters published on the homepage
- Yearly reports to VINNOVA
• Project reports
• Evaluation reports to VINNOVA

External communication
The objective is to inform about the Centre objectives and results to make students, researchers, industries and governmental agencies interested in work performed by the Centre.

• Advertising: Folders, cards, cups and jackets
• One yearly public whole day seminar – the Autumn seminar – on a topic relevant for the Centre
• Popular sciences articles in magazines like Sweden Today, Ny Teknik, Ingenjören
• Homepage
• Participation at conferences to present recent work within the Centre
• Some examples of already planned activities:
  o At the TRA conference 2008, prof. Annika Stensson Trigell et al. have been accepted to present an overview of the Centre, its research methodology and the innovative integrated industrial academic collaboration process, as well as the setup of joint projects requiring multi-disciplinarity and multi-vehicle focus.
  o The Centre will support the IAVSD conference 2009 that is arranged by KTH Vehicle Dynamics and KTH Rail Vehicles
  o The Centre will present its structure on the COMPERA seminar in Brussels March 2008
• Publication of research results in scientific journals
• Influencing the undergraduate courses with the ideas and research results of the Centre
• Annual report for external use

3.10 Learning Activities

Undergraduate education
During Phase II a list of relevant courses for the Centre will be established. This will make it possible to offer a specialization towards the area of ECO² vehicle design (“ECO² vehicle design engineering”) within the Master of Science Programme. During Phase II, increased focus will be on the integration of the activities within the Centre and the knowledge of the Centre into the undergraduate education. New courses will be developed when relevant.

Postgraduate education
During Phase II a formal package of courses for PhD students within the Centre will be established. This course package should be included in the individual study plan for all ECO² Vehicle Design PhD students. If needed, new PhD courses can be developed. The public autumn seminars within the Centre will also be a contribution to the PhD students to increase their knowledge within the area of ECO² vehicle design.

In order to facilitate the recruitment of PhD-students it is important that the marketing of the Centre also reaches the Master of Science students at KTH and that Master’s Thesis projects connected to the Centre is regularly offered.
4 Research Programme

4.1 Research Profile

The future competitiveness of the Swedish vehicle engineering industry may to a large extent depend on the success in designing ECO$^2$ compatible vehicles at an affordable cost, an art of engineering requiring validated design tools.

The core of the scientific programme of the Centre is to identify and perform research within vehicle design, with the ECO$^2$ requirements (see “Visions and Objectives”) acting as driving forces. In addition, the scientific programme is formed with a multidisciplinary and multi-vehicle perspective. All projects that are started within the Centre are required to be multidisciplinary and include more than one vehicle class. Special effort is given the process of identifying areas in vehicle design where conflicting requirements between two disciplines exist.

The Virtual Vehicles form an essential part of the scientific programme and are the tools for evaluation of the impact of the research results from the different projects. One Virtual Vehicle is defined for each vehicle class based on:

- vehicle class dependent design criteria
- 10 years horizon
- anticipating ECO$^2$ compatible novel engines/motors being state-of-the-art in that horizon

Project Generation Process

The project generation process is of vital importance for the initialization and development of projects within the Centre. The current process has emerged during Phase I and will be further developed during Phase II if necessary. Experiences of the process so far are good; one positive side effect is the greatly facilitated communication between the Centre partners directly linked to this exchange of ideas and criticism. Figure 4 illustrates the 20 week long project generation process, which consists of two major phases: the development of project ideas and the development of project proposals. The Centre welcomes project ideas from the partners for research within the scope of the Centre (0). It is necessary that the proposer has established contacts and preliminary approval for the project idea with relevant partners prior to submission (1, 2). The project ideas are distributed (3), discussed, developed and prioritized according to predefined criteria in cooperation with members of the CCG. A hearing (4) is held with the proposers and interested parties. Based on the hearing, the ideas can be reformulated (5), CCG discusses the newly formed ideas (6) and comments are distributed among the CCG members (7).

After approval in the CCG (8), the project ideas are developed into more detailed project proposals (9). An ambition at this stage of the project generation process is to identify synergy effects between different ideas and promote possible merger of project ideas into one project.
proposal. The final proposal is handed in to the CCG (10) which priorities among the submitted proposals (11) and gives recommendations to the Board (12). The Board in turn makes the decision on which projects that will be launched (13).

The Centre should prepare for later phases, where it is possible to successively introduce prototypes and demonstrators, to validate the concepts evolving from the research projects, and bring the systems engineering aspects more and more into focus. Through these hardware realisations, pre-concept as well as futuristic outlook studies may be performed. This would naturally lead to an increase in the turn-over, mainly due to the costs of building hardware, and most likely also lead to a natural enlargement of the partnership to e.g. relevant sub-contractors. It is foreseen that the level and scale of the prototypes will vary between technologies proposed, here the concept of Technology Readiness Level could be a useful frame for illustrating and monitoring this together with the continued substantiation of the Virtual Vehicles formulated for each vehicle class involved in the Centre.

4.2 Phase II, years 3 to 5

Research programme

The research projects initiated during the Phase I of the Centre are covering the following aspects of vehicle design: Crosswind Stability and Unsteady Aerodynamics in Vehicle Design, Multifunctional Body Panels, and ECO² Suspension Design. These projects have developed in different ways, but they have in common that they are multidisciplinary, cover multi-vehicles and include more than one PhD-student.

The Virtual Vehicles project and the effort related to inclusion of ECOlogical and ECOnomical aspects will continue to gain momentum. The virtual vehicles will also be used in the assessment of new ideas and running projects. One explicit effort will be made during Phase II to incorporate a systems engineering perspective on research projects. This is anticipated to strengthen the multidisciplinary and multi-vehicle coupling within and between activities.

For Phase II, further projects will be initiated and one proposal is related to human – vehicle interaction. Initially, the name of activities in this area has been “ECO² driving”. Efforts on active solutions to ECO² vehicle design problems are also discussed. Initial investigations within this area will be made with the aim to find possible ECO² related approaches and to seek appropriate collaboration.

The intent is to focus Phase II on Systems Engineering aspects and to initiate the next step to further incorporating the economical aspects in the Centre methodology, i.e. as additional constraints to the Virtual Vehicles. During Phase I, the Virtual Vehicle concept has been defined as part of the CCG activities. This tool was introduced to facilitate the evaluation of novel concepts for each of the targeted vehicle classes and to provide means for identification of the synergy effects gained when similar design aspects are relevant for different vehicle types. The activities have up to now been focused on the ecological constraints. Experiences from the early work show that there is a need to bring in additional academic competence on both these topics, the challenge being to formulate the ECO² constraints that influence the early design process, in a mathematical sense. From the start of Phase II, the research group Environmental Strategies Research – fms has joined the Centre, which will strengthen the competence on how to treat and assess ECO² aspects in a multidisciplinary way. It is anticipated that this inter-department collaboration will be of added value to the Centre as well as to the departments involved.
The involvement of individual experts from industry is an essential and highly critical function in a multidisciplinary research project, requiring multiple focal points from different industrial departments, and the associated complex interaction patterns and information exchanges that are necessary.

The Centre for ECO² Vehicle Design is part of a wide network of national centres focussing on vehicle related research, all more or less in the same phase of development and consolidation. As a result of this, each of the Centres has been able to focus on certain aspects of vehicle design. Thus it is a natural step at the onset of Phase II, to seek collaborative efforts on an inter-Centre basis, in order to strengthen the core research within the Centre.

In an international perspective, there are several ongoing activities on an individual basis, i.e. researchers active in the Centre participate in international projects within their disciplines. For the Centre as a whole, the Board has formulated a strategy for collaborative efforts targeting funding from sources outside of Sweden, e.g. the EU FP7 etc. This strategy follows a successive increase in the international presence of the Centre, which for Phase II implies that the consortium jointly will seek to enter into projects of different types as partner, while in later stages own initiatives are foreseen, i.e. taking the lead of a larger project proposal.

**Specific Projects**

The successful concept of the project generation process will remain during Phase II, why no specific future projects can be presented at this point. The generation of projects will however be focussed on areas of interests described in the research programme. Some future work within the ongoing projects can be seen below.

**Virtual Vehicles**

The activities within Virtual Vehicles have resulted in a target vehicle for each class represented in the Centre. Based on these, an evaluation tool has been developed for use in the project generation and assessment of ongoing projects. This tool will be used and evaluated initially during Phase II, and a first set of indicators is to be evaluated in the other ongoing projects. The ecological aspects are primarily evaluated in this tool, and among the indicators used are:

- Specific energy consumption (in kWh per km and person or net-ton)
- Specific CO₂ emission (in g per km and person or net-ton)
- External noise level (in dBA, maximal and equivalent)
- Track/road deterioration due to track/road forces from vehicles

For Phase II, activities are required to further link the virtual vehicles to ecological criteria and to develop the procedures to include economical aspects. Further activities should also initiate the work on systems perspective on ECO² Vehicle Design and a proposal is in the process of being defined. This proposal concerns an analysis of vehicles in their transport scenarios, thus naturally requiring an approach on a system level. This work is supposed to supply a greater understanding of the vehicle in the transport system to the partners in the Centre and generate ideas for new projects in ECO² vehicle design. As a result of efforts within the Virtual Vehicles projects, the division of Environmental Strategies Research (fms) at KTH is now a partner of the Centre. During Phase II, results from Virtual Vehicles and the continuation thereof will be disseminated through publication in scientific journals.

**Crosswind Stability and Unsteady Aerodynamics in Vehicle Design**

In this project the stability of trains, buses, trucks and cars due to transient crosswind is studied. Since the autumn 2006 all three PhD students are in place, and the project proceeds as planned.
One student finished his Licentiate Degree already in 2005 and is now working on measurement of steering feel and validation of wind loads, mainly for bus applications, aiming at the PhD degree in late 2008.

The other two students have carried out a literature study and are now doing initial work on transient aerodynamics and vehicle dynamics, respectively. During Phase II they will extend their work to more realistic scenarios and investigate different numerical methods and evaluation techniques. Some simple vehicle dynamics measurements have been carried out, in connection with the Green Train research programme, and wind tunnel tests are to be planned in close collaboration with the industry partners. Two Licentiate degrees are planned for in 2009.

Senior work is also carried out in the project, currently looking into various meshing techniques for aerodynamics simulations and comparison with existing measurements. How to treat complex vehicle geometries adequately will be studied further on in Phase II.

Throughout the project the main objective to is to propose less wind sensitive vehicle designs, or rather avoid increased crosswind sensitivity even though the vehicles are made lighter. By making the vehicles lighter reduced energy consumption, greenhouse gas effects, external noise levels and track/road deterioration are anticipated. The less wind sensitive vehicle designs should be mainly achieved through alternative external shaping and suspension systems.

**Multifunctional Body Panels**

Within the project *Multifunctional Body Panels* the potential benefits that may be realised in a multifunctional, integrated multi-layered structure design is investigated. One of several possible problem areas that are studied is whether the performance in terms of NVH and structural requirements, which may be far from optimal in the current component-based design methodology, can be enhanced at the same cost or maintained at a lower cost, where cost in this aspect is an overall measure (weight, manufacturing efficiency etc.). The initial work within the project has been focussing on car structures and engaged one PhD student. The expansion of the project, including involvement of a second PhD student and the incorporation of rail vehicle structures was realised at the end of Phase I. This project will continue during Phase II and result in two Licentiate degrees.

**ECO² Suspension Design**

The objective of the project *ECO² Suspension Design* is to increase the knowledge on how to develop vehicle suspension systems, under maintained handling and riding comfort, with for example reduced unsprung mass, rolling resistance, tyre wear, structure-borne noise, vibrations, suspension travel and/or tyre size. During Phase II the project continues working on the started subprojects in Phase I:

- A literature survey regarding the effect of suspension design and tyre characteristics on handling and comfort when tyre size and suspension travel are reduced. This is of interest since by reducing the suspension travel and using smaller wheels one can reduce the aerodynamic loads and increase load carrying capacity.
- Research on how the suspension design affects structure-borne noise. Already today a major issue in vehicles is structure-borne sound transmission that eventually is radiating as noise. Reduced tire size and suspension travel and also weight reductions all contribute to increased structure-borne sound transmission.
- Research on product verification within suspension design in order to make it more accurate and thereby make it possible to produce more accurate simulation models and reduce the number of real prototypes.
• Research on methodology for predication and analysis of driver comfort, handling and precision for construction machinery with wheel suspension. Today, construction machinery has no wheel suspension but to meet the increased demands on drivers working environment, a suspension system need to be introduced without affecting other important criteria for construction machinery such as maximum speed and precision of the dipper. Introducing wheel suspension makes it also possible to reduce the weight of the structure.

During Phase II the project will most likely be complemented with research on tyre’s rolling resistance and the influence of the road surface on the rolling resistance. The rolling resistance affects the fuel consumption and thereby it is an important issue both from an ecological and economical point of view. The project will during Phase II result in two Licentiate degrees and one PhD degree.

Competence Programme
The aim of this project is to provide resources for free explorative research, within the area of ECO² Vehicle Design, with the opportunity for in-depth research activities, including high quality theoretical, numerical and experimental investigations. The ultimate objective is to strengthen the knowledge base which is fundamental for the ability to pursue multidisciplinary research within the area. The activity is vital to the multidisciplinary approach that is the core of the Centre. The project also serves as a look-out for events and a source of new ideas and challenges for the future in order to identify promising research directions. The project involves mainly the faculty engaged in the AMG.

During Phase II, the work will develop through a joint investigation of a generic vehicle – one suggestion for such a generic vehicle is a “box on four wheel corners”. The objective is to improve the multidisciplinary / multi-vehicle methodology, while at the same time each researcher develops ones disciplinary research. The aim is to publish the results of the project both in disciplinary and interdisciplinary journals.

4.3 Gender perspective in the research programme
For researchers and students employed at KTH, the KTH policy for equality of opportunities applies. A breakdown by gender of the faculty and staff involved in the Centre as per 2007-10 looks like:

<table>
<thead>
<tr>
<th>Group</th>
<th>Female / Male</th>
</tr>
</thead>
<tbody>
<tr>
<td>Director</td>
<td>1 / 0</td>
</tr>
<tr>
<td>Board</td>
<td>1 / 9</td>
</tr>
<tr>
<td>CCG</td>
<td>6 / 12</td>
</tr>
<tr>
<td>AMG</td>
<td>3 / 2</td>
</tr>
<tr>
<td>PhD students</td>
<td>0 / 6</td>
</tr>
</tbody>
</table>

This illustrates two of the phenomena that several of the general KTH equality activities are focussed on; the difficulty to recruit female PhD students and the absence of female representatives in higher leadership positions.

5 Plan for measurement and evaluation of research and results in relation to the general and specific centre goals
To evaluate the research and results in order to become a World-Class research Centre within Vehicle Design, with the purpose to achieve more environmentally friendly and economically competitive rail and road vehicles, the following aspects will be measured:

- Number of scientific papers
- Number of popular science papers
- Number of conference proceedings
- Number of examined licentiates and doctors
- Percentage of all projects that are multidisciplinary
- Percentage of all projects that are multi-vehicle
- Partner commitment and involvement
- Number of prototypes
- The turnover of the Centre
- Number of seminars
- The ECO² indicator results of the Centre projects (the ECO² indicators will be developed through the Virtual Vehicles project)
- Number of persons involved in the Centre
- Number of satisfied partners
- Number of industry relevant innovations (IPR)

6 Comments on the recommendations to your Centre in the evaluation report, 11 October 2007.

These are the comments from the evaluators with the appropriate response or reference.

Our recommendations to ECO² are:

- That an effort be made to quantify the different aspects of the Virtual Vehicle to aid the project decision process but also to help in identifying achievements.

The project “Virtual Vehicles II” was formally terminated on 30 November 2007 and will present its final report in early 2008. This will contain suggestions for further work including a proposal for the continued development of the Virtual Vehicles in Phase II, where these aspects will be covered.

- That the research team keep in mind the synergies in the generation of models (for instance between buses and trains), or the simulation scenarios and, with particular emphasis, on the experimental model validation techniques.

The multidisciplinary nature of all ECO²-projects opens for such possible positive synergies, and this is alleviated by the presence of AMG-members in project groups.

- Although at this stage the approaches used to study Multifunctional Body Panels are exemplified by the application to the roof of a car, a more global and systematic approach should be used in the future.

As intended this generalisation of MFB results has been made clearer through the work done after the expansion of the project to include Bombardier Transportation, which has commenced since the VINNOVA evaluation.
• That ECO² seek other external research funding, nationally and internationally for example via EU Framework funds.

This question has already been brought to the attention of Board, and the AMG has been appointed the responsibility for an international strategy, and it will be implemented during Phase II.

• That ECO² immediately establish an International Scientific Committee.

We have initiated the establishment of the International Scientific Committee as part of the international strategy.

• That in the next round of financing ECO² member companies should provide cash contributions as well in-kind contributions.

According to the attached budget, each of the major industrial partners has agreed on a contribution consisting of both cash and in-kind.

• That in future years, the Board encourages the entry of new industry partners who would bring new expertise and resources to the Centre, particularly small- and medium-sized enterprises.

The Centre director and partner representatives are actively pursuing the market of possible new partners.

• That ECO² further develops its web presence and international profile to ensure its high quality research activities have maximum impact.

See the section on the communication plan above.

7 Financing Plan and Budget for Phase II

During Phase II, the Centre is expected to have a turnover of around 23 MSEK. The contributions from each partner are presented in Table 1. Note that part of the in-kind contributions from the industry is the salary of industrial PhD students. Other in-kind activates are experimental testing, participation in the CCG, project steering committees and serving on the board. Some of the research projects together with the Advance research activities and centre administration are continued from Phase I. The funding required for these activities are shown in Table 2.
### Table 1. Funding from each of the partners during Phase II.

<table>
<thead>
<tr>
<th>Part</th>
<th>Phase I</th>
<th>Phase II - Y1</th>
<th>Phase II - Y2</th>
<th>Phase II - Y3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>cash</td>
<td>in-kind</td>
<td>cash</td>
<td>in-kind</td>
</tr>
<tr>
<td>KTH</td>
<td>2874</td>
<td>4126,5</td>
<td>3000</td>
<td>4000</td>
</tr>
<tr>
<td>VINNOVA</td>
<td>5866</td>
<td>0</td>
<td>7000</td>
<td>0</td>
</tr>
<tr>
<td>Bombardier Transport</td>
<td>1250</td>
<td>1455</td>
<td>200</td>
<td>1800</td>
</tr>
<tr>
<td>Scania CV Aktiebolag</td>
<td>0</td>
<td>2262</td>
<td>200</td>
<td>1800</td>
</tr>
<tr>
<td>VTI</td>
<td>0</td>
<td>1323,5</td>
<td>200</td>
<td>1800</td>
</tr>
<tr>
<td>Saab Automobile Aktiebolaget</td>
<td>0</td>
<td>1864</td>
<td>200</td>
<td>1100</td>
</tr>
<tr>
<td>Banverket</td>
<td>0</td>
<td>0</td>
<td>700</td>
<td>0</td>
</tr>
<tr>
<td>Vägverket</td>
<td>875</td>
<td>168</td>
<td>400</td>
<td>100</td>
</tr>
<tr>
<td>A2 Zound by Semco</td>
<td>0</td>
<td>0</td>
<td>700</td>
<td>0</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td>11365</td>
<td>12135</td>
<td>11700</td>
<td>11400</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>23500</td>
<td>23100</td>
<td>23100</td>
<td>23100</td>
</tr>
</tbody>
</table>

### Table 2. Estimated costs for ongoing research projects and Centre activities

Within the ongoing projects, KTH are employing 6 PhD students, while 2 (year 3) and 1 (year 4 and 5) industrial PhD students are employed. As the centre activities are further progressed through the continuous activities on Advance research and facilitation, there will be funding available to start new activities, as seen in Table 3. At the time of writing this plan, in addition to those already active, 3 PhD students at KTH and 4 to 5 industrial PhD students are anticipated.
be employed by the end of Phase II. The aim is that the funding becoming available will be targeted to new research projects, while the current management level will be maintained. The global staff resources of the Centre are shown in Figure 5.

<table>
<thead>
<tr>
<th>Available funding (Msek)</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cash</td>
<td>In-kind</td>
<td>Cash</td>
</tr>
<tr>
<td></td>
<td>2980</td>
<td>4620</td>
<td>2980</td>
</tr>
</tbody>
</table>

**Table 3.** Funding available for new research activities during Phase II.

![Staff categories](image)

**Figure 5.** Expected faculty and staff engaged in the Centre. Note that the numbers are updated relative to the first application to Vinnova to reflect the current planning.

During Phase I, a discussion on the funding of the PhD students have been raised by several partners. For Phase II, the model shown in Table 4 will be implemented. For clarity, the in-kind contribution of KTH is explicitly identified. Regardless of where the student is employed, the costs for supervision by KTH are not charged as cash to the Centre budget.

<table>
<thead>
<tr>
<th>kSEK/year</th>
<th>KTH PhD student</th>
<th>Industrial PhD student</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cash from centre</td>
<td>In-kind KTH</td>
</tr>
<tr>
<td>Salary including OH</td>
<td>670</td>
<td>220</td>
</tr>
<tr>
<td>Supervision KTH</td>
<td></td>
<td>220</td>
</tr>
<tr>
<td>Supervision Industry</td>
<td></td>
<td>110</td>
</tr>
<tr>
<td>Total</td>
<td>1000</td>
<td>1000</td>
</tr>
</tbody>
</table>

**Table 4.** Funding model for PhD student engaged in the centre
## Board, ECO\(^2\) Vehicle Design 2008

<table>
<thead>
<tr>
<th>Name</th>
<th>Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Henrik Tengstrand (chair)</td>
<td>Bombardier Transportation AB</td>
</tr>
<tr>
<td>Staffan Berglund</td>
<td>Scania CV</td>
</tr>
<tr>
<td>Tohmmy Bustad</td>
<td>Banverket</td>
</tr>
<tr>
<td>Stefan Edlund</td>
<td>AB Volvo</td>
</tr>
<tr>
<td>Urban Emborg</td>
<td>A2Zound by Semcon</td>
</tr>
<tr>
<td>Anders Eriksson</td>
<td>KTH</td>
</tr>
<tr>
<td>Peter Göransson (vice chair)</td>
<td>KTH</td>
</tr>
<tr>
<td>Per-Olof Sturesson</td>
<td>Saab Automobile AB</td>
</tr>
<tr>
<td>Dan Zenkert</td>
<td>KTH</td>
</tr>
<tr>
<td>Malin Åkermo</td>
<td>KTH</td>
</tr>
<tr>
<td>Petter Åsman</td>
<td>Vägverket</td>
</tr>
</tbody>
</table>
## Centre Coordination Group, ECO² Vehicle Design 2008

<table>
<thead>
<tr>
<th>Name</th>
<th>Organization</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pia Öhrn</td>
<td>Bombardier Transportation AB</td>
<td>EM</td>
</tr>
<tr>
<td>Sebastian Stichel</td>
<td>Bombardier Transportation AB</td>
<td>TM</td>
</tr>
<tr>
<td>Klas Skog</td>
<td>Saab Automobile AB</td>
<td>EM</td>
</tr>
<tr>
<td>Thomas Carlberger</td>
<td>Saab Automobile AB</td>
<td>TM</td>
</tr>
<tr>
<td>Anna Henstedt</td>
<td>Scania CV</td>
<td>EM</td>
</tr>
<tr>
<td>Peter Holen</td>
<td>Scania CV</td>
<td>TM</td>
</tr>
<tr>
<td>Cecilia Gunnarsson</td>
<td>Volvo 3P</td>
<td>EM</td>
</tr>
<tr>
<td>Tommy Rosgardt</td>
<td>Volvo 3P</td>
<td>TM</td>
</tr>
<tr>
<td>Jack Samuelsson</td>
<td>Volvo CE</td>
<td>TM</td>
</tr>
<tr>
<td>Lars Ivarsson</td>
<td>A2Zound by Semcon</td>
<td></td>
</tr>
<tr>
<td>Staffan Nordmark</td>
<td>VTI</td>
<td></td>
</tr>
<tr>
<td>Jan Petzäll</td>
<td>Vägverket</td>
<td></td>
</tr>
<tr>
<td>Tohmmy Bustad</td>
<td>Banverket</td>
<td></td>
</tr>
<tr>
<td>Sara Tyskeng</td>
<td>KTH fms</td>
<td></td>
</tr>
<tr>
<td>Mats Berg</td>
<td>KTH</td>
<td>AMG</td>
</tr>
<tr>
<td>Susann Boij</td>
<td>KTH</td>
<td>AMG</td>
</tr>
<tr>
<td>Gunilla Efraimsson</td>
<td>KTH</td>
<td>AMG</td>
</tr>
<tr>
<td>Jenny Jerrelind</td>
<td>KTH</td>
<td>AMG</td>
</tr>
<tr>
<td>Per Wennhage</td>
<td>KTH</td>
<td>AMG</td>
</tr>
<tr>
<td>Annika Stensson Trigell</td>
<td>KTH</td>
<td>Centre director</td>
</tr>
<tr>
<td>Peter Göransson</td>
<td>KTH</td>
<td>Vice chair ECO² board</td>
</tr>
</tbody>
</table>

**EM** ECO² monitor  
**TM** Technology monitor  
**AMG** Assistant Management Group