rev2021 | Resource Efficient Vehicles Conference
14 – 16 June 2021

Conference Programme

Updated June 11, 2021

Contents

0. Programme Overview

rev2021	Day 1	Day 2	Day 3
	14-Jun	15-Jun	16-Jun
09:00	[OP1] Opening	[OP2] Opening	[OP3] Opening
09:10		[KN2] Keynote II	[KN4] Keynote IV
09:20	[ADD] Opening Address		
09:30			
09:40			
09:50	Break	Break	Break
10:00	[P01] Human-Vehicle Interaction I	[P06] Energy Consumption II	[P09] Materials and Modelling I
10:10			
10:20			
10:30			
10:40	Break	Break	Break
10:50			
11:00	[P02] Human-Vehicle Interaction II	[P07] Life Cycle Aspects I	[B16] Materials and Modelling II / Early Design I
11:10			
11:20			
11:30			
11:40	Break		Break
11:50	[P03] Component Design	[P08] Life Cycle Aspects II	[P11] Early Design II
12:00			
12:10			
12:20			
12:30	Lunch	Lunch	Lunch
12:40			
12:50			
13:00			
13:10			
13:20			
13:30	[MDS] Mingle Discussions	[WS1] Workshops	[P12] Systems Aspects I
13:40			
13:50			
14:00			
14:10	Break		Break
14:20	[P04] Driveline Aspects		[P13] Systems Aspects II
14:30		Break	
14:40			
14:50		[WS2] Workshops	
15:00	Break		
15:10			Break
15:20	[P05] Energy Consumption I		[PPD] Pre Panel Discussion
15:30			
15:40			
15:50		Break	
16:00	Break		Break
16:10	[KN1] Keynote I	[KN3] Keynote III	[PND] Panel Discussion
16:20			
16:30			
16:40			[CL3] Closing
16:50	[CL1] Closing	[CL2] Closing	
17:00	End	End	End

1. Day 1 Sessions

[OP1] Opening

Mon, 14-Jun, 09:00-09:20 CEST
Chaired by Ciarán O'Reilly and Jenny Jerrelind

Opening of the conference

Welcome to *r*ev2021 Day 1!

Here, there is an opening ceremony for the conference.

All participants are welcomed and an overview of the conference is provided.

[ADD] Opening Address

Mon, 14-Jun, 09:20-09:50 CEST
Chaired by Ciarán O'Reilly and Jenny Jerrelind

Research and development strategies for resource efficient vehicles
Staffan Berglund

[P01] Human-Vehicle Interaction I

Mon, 14-Jun, 10:00-10:40 CEST
Chaired by Mikael Nybacka and Jenny Jerrelind

P01.A
Autonomous driving and motion sickness – an outlook on causes, evaluation methods and solutions
Ilhan Yunus, Jenny Jerrelind and Lars Drugge

P01.B
An experiment in efficient interaction between a passenger and AI in an Autonomous Vehicle through an Aurovisual communication model
Peer Sathikh, Guan Yi Tan and Zong Rui Dexter Fang

P01.C
Psychoacoustic perspectives on electric truck
Maria Ekman

[P02] Human-Vehicle Interaction II

Mon, 14-Jun, 11:00-11:40 CEST
Chaired by Margriet Van Schijndel-de Nooij and Carlos Casanueva Perez

P02.A
Optimising tyre wear and exploring its conflict with comfort
Georgios Papaioannou, Jenny Jerrelind and Lars Drugge

P02.B
Human Machine Interface: A review for future applications in train driving
Simon Enjalbert, Livia Maria Gandini, Alexandre Pereda-Baños, Stefano Ricci and Frederic Vanderhaegen

P02.C
Objective development in driving simulator motion control: Evaluation of motion cueing using a linearised driving simulator model
Henrik Hvitfeldt, Jenny Jerrelind and Lars Drugge

[P03] Component Design

Mon, 14-Jun, 11:50-12:30 CEST
Chaired by Giuseppe Petrone and Per Wennhage

P03.A
Structural analysis of vehicle frames using higher-order beams
Jaeyong Kim, Gang-Won Jang and Yoon Young Kim

P03.B
Design of multifunctional structures using topology optimization for conflicting structural and acoustic requirements
Johan Larsson, Peter Göransson and Per Wennhage

P03.C
Redesign and structural optimization for lightweighting of a truck door
Jan Stroobants, Freek de Bruijn, Saïcha Gerbinet, Jean Pierre Heijster, Carlos López, Reginald Diltoer, Jasper Mols, Johan Potargent, Angélique Léonard, Elke Deckers, Bert Pluymers and Philip Eyckens

[MDS] Mingle Discussions

Mon, 14-Jun, 13:30-14:10 CEST
Chaired by Susann Boij and Peter Göransson

The rev2021 networking forum

Welcome to the social and networking forum of the conference!

Throughout the conference, the virtual meeting space Gather.Town is available in parallel to the main Zoom meetings, so connecting and discussing with other participants is just a click away.

In this session, Gather.Town is introduced. The day's speakers are available to discuss their presentations. Also, participants can discuss the conference's hot topics, contribute with new topics, or have spontaneous meetings and chats with others.

[P04] Driveline Aspects

Mon, 14-Jun, 14:20-15:00 CEST
Chaired by José Luis Olazagoitia and Eva Lundberg

P04.A
Methodology for the design of Stirling thermoacoustic engines based on the reactive power
Carmen Iniesta, Jaime Gros, José Luis Olazagoitia, Jordi Vinolas and Javier Aranceta

P04.B
Hydrogen powered trains challenges: normative constraints and operational assessment
Livia Maria Gandini, Stefano Ricci and Francesca Verrascina

P04.C
Product cost assessment in the early development phase of powertrain systems
Simon Röhrenbacher, Oliver Moerth-Teo, Lukas Schwarz, Hans Schnöll and Christian Ramsauer

[P05] Energy Consumption I

Mon, 14-Jun, 15:20-16:00 CEST
Chaired by Mario Hirz and Malte Rothhämel

P05.A
A more efficient braking system for heavy vehicles
Pontus Fyhr and Leon Henderson

P05.B
Development of rolling resistance measurement set-up in order to enable energy optimisation of vehicle-road interaction taking into account safety and performance
Lisa Ydrefors, Mattias Hjort, Sogol Kharrazi, Jenny Jerrelind and Annika Stensson Trigell

P05.C
Regenerative braking for an electric vehicle with a high-speed drive at the front axle
Ektor Karyotakis, Rémi Mongellaz and Mathias Lidberg

[KN1] Keynote I

Mon, 14-Jun, 16:10-16:50 CEST
Chaired by Romain Rumpler and Mathilda Karlsson Hagnell

A sustainable transport sector: Opportunities and challenges in the European Green Deal context
Marzia Traverso

[CL1] Closing

Mon, 14-Jun, 16:50-17:00 CEST
Chaired by Romain Rumpler and Mathilda Karlsson Hagnell

Closing 1

The end of Day 1.

Here, the day's events are briefly summarised and there is a look ahead to the remainder of the conference.

2. Day 2 Sessions

[OP2] Opening

Tue, 15-Jun, 09:00-09:10 CEST
Chaired by Jenny Jerrelind and Peter Göransson

Opening of Day 2

Welcome to *r*ev2021 Day 2!

Here, there is an overview of the day's activities.

[KN2] Keynote II

Tue, 15-Jun, 09:10-09:50 CEST
Chaired by Jenny Jerrelind and Peter Göransson

Resource efficient mobility: What does it take?
Margriet Van Schijndel-de Nooij

[P06] Energy Consumption II

Tue, 15-Jun, 10:00-10:40 CEST
Chaired by Mathias Lidberg and Rickard Persson

P06.A
Development of a vehicle-road interaction analysis framework for truck tyres
Jukka Hyttinen, Rickard Österlöf, Jenny Jerrelind and Lars Drugge

P06.B
Possible reduction of energy consumption with single axle running gear
Rickard Persson, Zhendong Liu and Rocco Giossi

P06.C
Cargo bikes - sustainable means of transportation
Saskia Biehl, Heinz Kaufmann, Artur Schönemann, Tobias Melz, William Kaal and Wilfried Kolodziej

[P07] Life Cycle Aspects I

Tue, 15-Jun, 11:00-11:40 CEST
Chaired by Mathias Janssen and Ciarán O'Reilly

P07.A
Potential for CO2 equivalent emission reduction in future passenger car fleet scenarios in Europe
Thu Trang Nguyen, Helmut Brunner, Mario Hirz, Alexander Rust and Johann Bachler

P07.B

An investigation of robust design and uncertainty quantification within the life cycle energy optimisation methodology
Hamza Bouchouireb, Ciarán J. O'Reilly and Peter Göransson

P07.C
Life Cycle Assessment of heavy-duty distribution vehicles
Dora Burul and David Algesten

[P08] Life Cycle Aspects II

Tue, 15-Jun, 11:50-12:30 CEST
Chaired by Marco Pierini and Mathilda Karlsson Hagnell

P08.A
System-wide impact of vehicle innovations – Evaluating Track-friendliness during vehicle design
Carlos Casanueva, Visakh V Krishna and Sebastian Stichel

P08.B
A life cycle energy and weight comparison of a carbon fiber composite versus metallic component in a commercial vehicle
Sara Eliasson, Mathilda K. Hagnell, Robert Jonsson, Per Wennhage and Zuheir Barsoum

P08.C
The environmental benefits and challenges of the composite car with structural battery materials
Frida Hermansson, Ivan Berg, Kevin Sandberg, Leif E. Asp, Matty Janssen and Magdalena Svanström

[WS1] Workshops

Tue, 15-Jun, 13:30-14:30 CEST
Chaired by Mathilda Karlsson Hagnell, Per Wennhage and Malte Rothhämel

Parallel Workshop

Note, the workshops WSA, WSB and WSC are offered in parallel. Participants should register in advance for the workshop they wish to take part in.

WSA
Making good decisions – Managing sustainability issues on heavy-duty powertrain systems during the early design stage
Vassiliki Theodoridou, Josef-Peter Schöggl, Katharina Berger, Rupert J. Baumgartner

WSB
Reimagining a more circular transport system
Lili-Ann Laan

WSC
Electrification strategy for road vehicles
Malte Rothhämel

[WS2] Workshops

Tue, 15-Jun, 14:50-15:50 CEST
Chaired by Carlos Casanueva Perez, Mathilda Karlsson Hagnell and Per Wennhage

Parallel Workshop

Note, the workshops WSA, WSB, WSD are offered in parallel. As WSA and WSB are continuing, new participants can not join. However, new participants may join WSD. Participants should register in advance for the workshop they wish to take part in.

WSD
Innovation modelling for system impact calculations
Jordi Vinolas

WSA (continued)
Making good decisions – Managing sustainability issues on heavy-duty powertrain systems during the early design stage
Vassiliki Theodoridou, Josef-Peter Schöggl, Katharina Berger, Rupert J. Baumgartner

WSB (continued)
Reimagining a more circular transport system
Lili-Ann Laan

[KN3] Keynote III

Tue, 15-Jun, 16:10-16:50 CEST
Chaired by Ciarán O'Reilly and Romain Rumpler

Driving toward zero in California: How steep a hill must we climb?
Lewis Fulton

[CL2] Closing

Tue, 15-Jun, 16:50-17:00 CEST
Chaired by Ciarán O'Reilly and Romain Rumpler

Closing 2

The end of Day 2.

Here, the day's events are briefly summarised and there is a look ahead to the remainder of the conference.

3. Day 3 Sessions

[OP3] Opening

Wed, 16-Jun, 09:00-09:10 CEST
Chaired by Carlos Casanueva Perez and Susann Boij

Opening of Day 3

Welcome to *r*ev2021 Day 3!

Here, there is an overview of the day's activities.

[KN4] Keynote IV

Wed, 16-Jun, 09:10-09:50 CEST
Chaired by Carlos Casanueva Perez and Susann Boij

Resource efficient rail transport systems: A railways perspective to REV
Sebastian Stichel

[P09] Materials and Modelling I

Wed, 16-Jun, 10:00-10:40 CEST
Chaired by Elke Deckers and Romain Rumpler

P09.A
Green chips urethane based poroelastic materials: an opportunity for up to 80% recycled and 100% recyclable content coming from recycled PU mattresses
Arnaud Duval, Guillaume Crignon, Maxime Roux and Dominique Lemaire

P09.B
Periodic resonator-based optimization of an acoustic package made of glass wool
Giuseppe Catapane, Dario Magliacano, Giuseppe Petrone, Francesco Franco and Sergio De Rosa

P09.C
3D tunable anisotropic metamaterial for low-frequency vibration absorption
Huina Mao, Romain Rumpler and Peter Göransson

[P10] Materials and Modelling II / Early Design I

Wed, 16-Jun, 11:00-11:40 CEST
Chaired by Thilo Bein and Peter Göransson

P10.A
Analytical method for predicting micro-geometry-based flow resistivity in anisotropic foams to improve sound absorption of vehicle panels
Eva Lundberg, B. P. Semeniuk, Huina Mao, Romain Rumpler and Peter Göransson

P10.B
Optimization of deep drawing process parameters for multiple functional requirements
V. K. Balla, E. Deckers, B. Pluymers, J. Stroobants, H. G. Sakinala and W. Desmet

P10.C
Systematic design of a generic Life Cycle Assessment model construct for aluminum automotive components
Patrick Haun, Philipp Müller and Marzia Traverso

[P11] Early Design II

Wed, 16-Jun, 11:50-12:30 CEST
Chaired by Tracy Bhamra

P11.A
Concept of a digital product passport for an electric vehicle battery
Katharina Berger, Josef-Peter Schöggl and Rupert J. Baumgartner

P11.B
A generic approach to capitalize manufacturing experience in design and optimization
Philip Eyckens, Frank Naets, Elke Deckers, Eveline Rosseel, Hendrik Schuette, Ioanna Koutla, Reginald Diltoer, Carlos Lopez and Pierre Duysinx

P11.C
Validation of a novel XiL setup for frontloaded testing of an electric vehicle powertrain
Bart Forrier, Thomas D'hondt, Leonardo Cecconi and Mathieu Sarrazin

[P12] Systems Aspects I

Wed, 16-Jun, 13:30-14:10 CEST
Chaired by Arnaud Can and Per-Olof Sturesson

P12.A
A methodology to assess the impact of driving noise from individual vehicles in an urban environment
Sacha Baclet, Siddharth Venkataraman and Romain Rumpler

P12.B
Analyzing interaction effects in a vehicle model using network theory
Sai Kausik Abburu, Carlos Casanueva Perez and Ciarán O'Reilly

P12.C
Open-source modeling chain for the dynamic assessment of road traffic noise exposure
Valentin Lebescond, Arnaud Can, Pierre Aumond and Pascal Gastineau

[P13] Systems Aspects II

Wed, 16-Jun, 14:20-15:10 CEST
Chaired by Gyözö Gidofalvi and Susann Boij

P13.A
Using Analytical Hierarchy Process (AHP) to introduce weights to Social Life Cycle Assessment of Mobility Services
Katharina Gompf, Marzia Traverso and Jörg Hetterich

P13.B
An initial exploration of measures of transport efficiency through optimising a simple truck model
Khashayar Shahrezaei, Ciarán O'Reilly, Timo Lähivaara and Peter Göransson

P13.C
Towards a multi-scale and multi-domain modelling of road cargo systems
Per-Olof Sturesson and Stefan Edlund

P13.D
On the trade-off between noise exposure cost and resource efficiency in traffic
Johan Nygren, Susann Boij, Romain Rumpler and Ciarán J. O'Reilly

[PPD] Pre Panel Discussion

Wed, 16-Jun, 15:20-16:00 CEST
Chaired by Mathilda Karlsson Hagnell and Per Wennhage

Presentation of all panelists

The panelists participating in the upcoming panel discussion present themselves and give their view on sustainability and product development challenges facing their vehicle systems, disciplinary backgrounds and organisations.

The panelists are Jonas Eliasson, Director of Transport Accessibility at Trafikverket (The Swedish Transport Administration); Elisabeth Hörnfeldt, Project Manager of Sustainable Integrated Transport Systems at Scania Group; and David Wennberg, Rail Systems Specialist and Co-Founder of WMC Consulting.

[PND] Panel Discussion

Wed, 16-Jun, 16:10-16:40 CEST
Chaired by Annika Stensson Trigell

Research and development for future resource efficient vehicles

Future resource efficient vehicles need to fulfill different engineering and sustainability challenges. How can research help meet these challenges?

Annika Stensson Trigell, KTH Royal Institute of Technology's Vice-Rector for Research, is joined by Jonas Eliasson, Elisabeth Hörnfeldt and David Wennberg to discuss this topic.

[CL3] Closing

Wed, 16-Jun, 16:40-17:00 CEST
Chaired by Ciarán O'Reilly

Closing of the conference

The end of Day 3 and the final day of *r*ev2021.

Here, there is a closing ceremony.

Thank you to everyone who contributed to this conference and see you all at the next Resource Efficient Vehicles conference!

4. Invited Speakers

ADD

Research and development strategies for resource efficient vehicles

Staffan Berglund

Staffan is Director of Engineering at Scania Group and Chairman of the Board of the Centre for ECO^2 Vehicle Design.

The transport industry has always worked to develop resource efficiency in vehicles to meet the customers' demands. Now in the context of sustainability, the transport industry must improve their strategies to support even faster problem solving with an even better holistic view. This presentation looks at how the ECO2 strategies – of taking a cross-scalar view, solving cross-functional conflicts, and promoting cross-fertilisation of ideas – contribute to resource efficient vehicles.

KN1

A sustainable transport sector: Opportunities and challenges in the European Green Deal context

Marzia Traverso

Marzia is Professor and head of the Institute of Sustainability in Civil Engineering at RWTH Aachen.

After the Paris Agreement the European Union has developed the European Green Deal which represents the response to the challenges the world and Europe are facing in reducing its impact to the climate change. It is a growth strategy proposed by the von der Leyen Commission to make Europe the first climate neutral continent by 2050. The main idea is to transform the economy into a clean and circular system, while cutting pollution and restoring biodiversity (A European Green Deal).

According to the European Commission (EC), to reach this 2050 target the following actions are needed: investments in eco-friendly technologies, clean public and private transport, support for research and innovation, decarbonisation of the energy sector, more efficient buildings, and environmental recovery.

KN2

Resource efficient mobility: What does it take?

Margriet Van Schijndel-de Nooij

Margriet is Program Director of Smart Mobility at Eindhoven University of Technology.

In striving for zero emission mobility, a large focus is on electric vehicles; development, testing and implementation. Needless to say that these vehicles still do create emissions, though less on the time and location of its use. We also do have other modes of mobility which are quite resource efficient. What about them? And what about AI; it often is seen as enabler for automated mobility. Yet, in resource efficiency it can play an essential role as well.

KN3

Driving toward zero in California: How steep a hill must we climb?

Lewis Fulton

Lew is Director of the Sustainable Transportation Energy Pathways (STEPS+) at UC Davis.

California has set a state-level target of net zero CO2 emissions economy wide by 2045. The transportation sector must play its part and needs to reach as close to zero emissions by that date as possible. This talk covers the potential strategies for deep cuts in in-state CO2, primarily focusing on the light- and heavy-duty road vehicle sectors. It reports on a new state-wide study that finds that very rapid transitions to near-zero vehicle technologies, coupled with very low carbon fuels, will be needed. Policies will be needed that challenge political acceptability boundaries. It presents scenarios and considers the transitional and policy challenges for the state, and implications for states and countries around the world.

KN4

Resource efficient rail transport systems: A railways perspective to REV

Sebastian Stichel

Sebastian is Professor in Rail Vehicle Dynamics at KTH Royal Institute of Technology and Director of the KTH Railway Group.

Railway Transport is already today in several aspects a resource efficient transport system. It is very energy efficient, has low CO2 emissions since it is easily electrified, has a high transport capacity in relation to the land use, and it is very safe. Nevertheless, researchers and vehicle manufacturers are working on further reducing energy consumption and emissions from rail vehicles with e.g., lightweight designs, reduced air drag or novel and optimized propulsion systems. Also, the infrastructure, is a very important an integral part of the system, where construction of new railway lines leads to substantial CO2 emissions in the building phase. Ongoing developments will be shown in the presentation. Another possible contribution to a more sustainable transport system is to change the modal split, i.e., to increase the share of rail transport as part of the whole transport volume, which is propagated for example by the EU. To increase the share of railway transport, it must be made as attractive and cost efficient as possible. Thus, in the presentation aspects of a more attractive railway system will be discussed as well.

5. Workshop Descriptions

WSA

Making good decisions – Managing sustainability issues on heavy-duty powertrain systems during the early design stage

Vassiliki Theodoridou, Josef-Peter Schöggl, Katharina Berger, Rupert J. Baumgartner

Trucks, buses and coaches are responsible for about a quarter of CO2 emissions from road transport in the EU and despite some improvements in fuel consumption efficiency in recent years, these emissions are still rising. In order to fulfil the need for a more sustainable transportation the EU adopted in 2019 the CO2 emission standards for heavy-duty vehicles, by setting targets for reducing the average emissions from new lorries for 2025 and 2030. Since eighty percent of the product-related environmental burdens are determined within the early stage of design, it is obvious that managing sustainability issues on this stage will be a key success factor.

Using proper tools and methods as well as the deeper understanding of all these issues from people involved in the product design can make this goal a reality. This workshop presents the most promising concepts to tackle this challenge. The advantages and possible weakness of the various methods will be briefly presented. Furthermore, by highlighting the main drivers for sustainability issues product designer and engineers will gain an overview of "what truly matters" to be considered when picking the best path forward. The interactive session included aims to explore and discuss in detail the special topics of

- data availability,
- sustainability awareness – awareness of the main drivers for sustainability issues
- tools and methods used and their bottlenecks

WSB

Reimagining a more circular transport system

Lili-Ann Laan

Even before the Covid crisis, the E-commerce industry was on the rise, but due to recommendations to stay at home and keeping distance, it has been an absolute e-commerce boom. People order groceries, pharmacy goods, clothes, and technical devices online as never before, and demand for new solutions focusing on receiving the goods has never been higher. Thus, the role as a consumer is well facilitated. But how about the role as a producer of waste and discontinued products?

During this workshop, we will highlight the returning flow and shift the focus from package to waste. Can we design a more circular transport system by considering behaviors, vehicle concepts, and services? Welcome to a workshop where we together try to reimagine a more sustainable future.

WSC

Electrification strategy for road vehicles

Malte Rothhämel

Electrification of road traffic is seen as the best actual known strategy to make this mode of transportation more sustainable. It enables higher efficiency, specifically on short distances, low local emissions and moves the focus on efficiency in total as well as life cycle analysis.

Anyhow, there are several thresholds, and the success of electric mobility will not only be a question of technology but also a question of policy. The organisation of establishing charging infrastructure is only one of them.

In this workshop an electrification strategy will be presented as subject of discussion. The goal is to

collect different perspectives on that and to discuss them. Even variants and alternatives can be picked out. The expected outcome is a broader view on this topic for all participants and in the best-case new ideas and inspiration for future research.

WSD

Innovation modelling for system impact calculations

Jordi Vinolas

When studying innovations in vehicle components it is usually straightforward its influence on the vehicle, but it can be hard to predict what their system-wide impact would be, as the interfaces are usually unclear, the subsystems belong to different stakeholders, and the stakeholder interactions are not necessarily governed by rational decisions.

In this workshop, participants in the EU project NEXTGEAR will be present and discuss this from a cost modelling perspective, showcasing the possibilities and allowing you to apply the methods and techniques for analysing the impact of selected vehicle innovations on the specific vehicle system context, in order to enable the complete understanding of the cascading effects generated by specific subsystem changes.

6. Paper Abstracts

P01.A

Autonomous driving and motion sickness – an outlook on causes, evaluation methods and solutions

Ilhan Yunus, Jenny Jerrelind and Lars Drugge

The development of autonomous vehicles is rapidly moving forward through significant efforts from the automotive industry and researchers. The design and the usage of the vehicles can drastically change, leading to a transformation of the vehicle-transport system. One key enabler for the complete success of autonomous vehicles is to design and control the vehicle so that the passengers do not become motion sick. There is therefore a need to investigate what causes motion sickness and how motion sickness can be evaluated. This includes the medical understanding of what is causing motion sickness to understand the human aspects of a range of motion-related parameters such as accelerations, vibrations, etc. Furthermore, with the help of modelling detect and predict motion sickness. There exist today different models to predict and evaluate motion sickness, but they are often rather limited and not directly usable as tools in the vehicle development process. There are both empirical and theoretical approaches used in the modelling of motion sickness, which have different advantages and disadvantages to each other. In this paper, the causes of motion sickness and some existing motion sickness models will be discussed. With the help of identified motion sickness prediction models, new technical innovations needed within vehicle dynamics control and motion planning control can be developed to minimise the risk of motion sickness in autonomous vehicles. Motion sickness prediction models are important tools in the early design stage of development on how to control and design autonomous vehicles so that the functional conflict between safety, comfort and performance is handled for the complete success of autonomous vehicles when it comes to economic and social benefits.

P01.B

An experiment in efficient interaction between a passenger and AI in an Autonomous Vehicle through an Aurovisual communication model

Peer Sathikh, Guan Yi Tan and Zong Rui Dexter Fang

In present ride-hailing contexts, passengers are used to communicating with a driver during a ride. However, the introduction of Autonomous Vehicles (AVs) presents an interesting scenario, as the AV has no physical driver on board. Yet a level of fear still exists, as the public is unable to fully predict or understand its intentions. The concept of an Omnipresent AI was introduced, allowing for the AI to achieve a sense of presence through 3 postulates previously developed. A simulated roadtrip scenario experiment was done to ascertain the indicators towards further testing these 3 postulates. This paper outlines these indicators obtained from the experiment could form an important part of future research.

P01.C

Psychoacoustic perspectives on electric truck

Maria Ekman

It has been clear that we need to lower our dependance of fossil fuels. As a part of this, could be to use electric drive instead of fossil fuels in cars and electric heavy vehicles. By using psychoacoustics measurement, this paper gives a brief outlined of planning work of determining the interior sound quality within electric heavy vehicles.

P02.A

Optimising tyre wear and exploring its conflict with comfort

Georgios Papaioannou, Jenny Jerrelind and Lars Drugge

The automotive industry is shifting its focus on energy efficient driving to tackle rising environ- mental issues. In this direction, as exhaust particle emissions continuously decrease, the attention is turned on non-exhaust traffic related sources in ground vehicles, such as the interaction between tyre and roads and the tyre wear. Given that the tyres are costly for the vehicle owner and wear cre- ates large waste of old tyres, the modelling and the minimisation of tyre wear have been of great interest recently. The tyre wear is mainly caused by inner (tyre structure and shape) and external (suspension configuration, speed, road surface, etc.) factors. So, this work presents a sensitivity analysis of both inner and external factors, and then explores the optimisation of tyre and sus- pension parameters for minimising tyre wear and enhancing comfort. More specifically, initially the inner factors are investigated regarding their impact on tyre wear, while external factors, i.e., vehicle loading, velocity and road type, which can be different daily regarding the purpose of the ride, are studied regarding both comfort and tyre wear outlining the conflicting relation between these two objectives. Finally, informed by the results, the optimum tyre and suspension design for a passenger vehicle are sought to both minimise tyre wear, enhance comfort and improve vehicle stability in normal loading conditions while the vehicle drives in a city road (Road Class A) with normal speed.

P02.B

Human Machine Interface: A review for future applications in train driving

Simon Enjalbert, Livia Maria Gandini, Alexandre Pereda-Baños, Stefano Ricci and Frederic Vanderhaegen

The paper deals with the description of preliminary research work based on extended investigation focused on categorized Human Machines Interface (HMI), describing their technical approaches and emerging operational issues. The study aims at reviewing and analysing HMI, their design and control systems currently on the market or in experimental operation. The analysis acts as a review manual on HMI technologies to design customized HMI and analyse the technologies used or tested in the present technological scenario. The paper starts by addressing the systems developed by manufacturers of surface vehicles outside railway field: trucks, cars and ships. It follows with the performances of simulators developed for various transport systems: rail, cars, aviation and integrated solutions. Finally, the focus is on the comparative analysis of the performances of supporting tools for train drivers assistance, a synthetic analysis of results and the organization of the survey among drivers to check expectations and acceptance of potential solutions.

P02.C

Objective development in driving simulator motion control: Evaluation of motion cueing using a linearised driving simulator model

Henrik Hvitfeldt, Jenny Jerrelind and Lars Drugge

Even though the automotive industry is heading towards a more objective approach to vehicle testing, subjective evaluation is still an important part of the development process. Subjective evaluation in physical testing has environmental implications and is a function of ambient settings. A more repeatable, faster, safer, and more cost-effective tool for subjective evaluation is to use moving base driving simulators (MBDS). The increasing usage of MBDS in the automotive industry is due to an increasing demand of rapid development and usage of virtual prototyping. The motion cueing algorithms (MCA) maps the movement of the vehicle into the limited space of the simulator. The MBDS could potentially enable a ”human in the loop” in the virtual development process, enabling early phase subjective testing. This

research aims to develop an objective framework for the validation of MCAs to close the loop on virtual development. The state-of-the-art MCAs are commonly developed and validated subjectively. This causes a tendency to false ques, limited assurance of MCA fidelity and demands physical vehicles for validation, which hinders early phase development. This paper presents a linear driving simulator model based on existing linear models for planar vehicle dynamics, classic motion cueing and human vestibular response. The model can capture important characteristics of the specific forces and rotations that are fed to the driver, through the motion cueing algorithms and offering a method to objectively analyse and potentially tune the motion cueing. The method is applied to the choice of reference point of acceleration in the vehicle to feed the motion cueing, and results indicate that a reference point at the driver's head has a clear advantage compared to a reference point in the chassis over the full frequency range.

P03.A

Structural analysis of vehicle frames using higher-order beams

Jaeyong Kim, Gang-Won Jang and Yoon Young Kim

Using one-dimensional analysis models such as a beam-based model can be efficient in the early- stage design because of their simplicity and analysis efficiency. Despite these advantages, they have not been much explored in the vehicle industry because of their poor accuracy. This is mainly because conventional one-dimensional models using the Euler-Bernoulli or Timoshenko beams considering only six sectional rigid-body modes are incapable to represent stiffness weakening caused by complex deformations due to distortion and warping which cannot be ignored in thin- walled beam members forming a vehicle frame. To account for these complex deformations, a beam model should be capable to represent higher-order sectional modes in addition to the sectional rigid-body modes. In the case of straight beams, the resulting higher-order beam analysis is found to predict nearly as accurate results as obtained by refined plate-based analysis. However, it has remained to be difficult to obtain satisfactory results using a higher-order beam theory for a vehicle frame having a number of beam-joints because the exact field matching conditions for the higher-order modes at a joint are difficult to establish for beams of arbitrarily-shaped cross- sections. This difficulty comes from the fact that the higher-order modes generate no stress resultant over the beam cross-section, making the coordinate transformation matrix commonly used for the sectional rigid-body modes invalid for the case of the higher-order modes. Here, we newly propose an approach to define the joint condition for a one-dimensional higher-order beam model that is applicable to the higher-order modes as well as the sectional rigid-body modes. To confirm the validity of the proposed method, several numerical case studies are examined, including static and modal analyses of a simplified vehicle frame made of beams of various c ross-sections.

P03.B

Design of multifunctional structures using topology optimization for conflicting structural and acoustic requirements

Johan Larsson, Peter Göransson and Per Wennhage

Topology optimization is used to design multifunctional sandwich panels that fulfill multiple func- tional constraints. The purpose is to expand the methodology for multifunctional design in early stages of the vehicle design process, to allow for design of multifunctional vehicle systems that can replace multiple subsystems and reduce the total mass of the vehicle. The focus of the re- search is the inclusion of dynamic behaviour into the topology optimization framework. The case study for this research is a train cabin sandwich structure, with the functional requirements being the structural and acoustic properties of the structure. The core of the sandwich panel is the design domain of the optimization . The problem is modelled and solved as a mass minimization topol- ogy optimization problem with the structural requirements being translated into constraints on the static response of the structure and the acoustic requirements being translated into constraints on the response when subjected to time-harmonic loads. The topology

optimization problem is solved using the Topology Optimization of Binary Structures (TOBS) method.

P03.C

Redesign and structural optimization for lightweighting of a truck door

Jan Stroobants, Freek de Bruijn, Saïcha Gerbinet, Jean Pierre Heijster, Carlos López, Reginald Diltoer, Jasper Mols, Johan Potargent, Angélique Léonard, Elke Deckers, Bert Pluymers and Philip Eyckens

To advance on automotive lightweighting and sustainability, different design strategies can be followed, such as material substitution, functionality integration, structural design optimization and design for novel production processes. In the presented ab initio re-design use case of a truck door, all these strategies are combined to realize substantial weight reduction in combination with improved life cycle assessment. The traditional steel sheet body is hereby replaced with a short- fiber reinforced PE shell structure designed for a novel robomoulding process, and supported by a steel beam structure as an insert in the same production process. This contribution focuses on the various adopted strategies for structural design optimization throughout the design process, from the early conceptual design up to the detailed design and the validation stage. In early design stage, a simplified quasi-2D model is established to optimize the placement of a beam structure under static and vibrational load cases. In this process, a few hundred automatically generated and evaluated beam structures have been considered within an in-house design software tool. In the subsequent, detailed design stage, further FE-based optimization of the structural part is performed starting from a (3D) CAD design for additional lightweighting while retaining structural requirements. In this step, a commercial design optimization tool is adopted. The result is an optimized design with integrated functionalities, a mass reduction of at least 10 % and a corresponding reduction in CO2eq emissions. The optimized design will be realized as a physical prototype.

P04.A

Methodology for the design of Stirling thermoacoustic engines based on the reactive power

Carmen Iniesta, Jaime Gros, José Luis Olazagoitia, Jordi Vinolas and Javier Aranceta

The recovery of residual thermal energy is a critical issue in many industrial processes and engines. Stirling thermoacoustic engines are proving to have an interesting potential for recovering energy. The description of the internal physical phenomena to support the design process of these devices is far from simple. Conventional methods only consider so far, the flow of “active power” circulating, and do not pay attention to the “reactive power” that also flows through the system. This communication presents a simple methodology to analyse the energy flow (active and reactive power) for Stirling thermoacoustic engines. The results show that the amount of reactive acoustic power distributed towards the core branch is a good indicator of the grade of traveling-wave phasing. This new indicator can be used as an effective tool to design and study thermoacoustic devices.

P04.B

Hydrogen powered trains challenges: normative constraints and operational assessment

Livia Maria Gandini, Stefano Ricci and Francesca Verrascina

The use of hydrogen-powered propulsion in railways is very promising and already found relevant commercial applications. Some potential barriers emerged anyway as critical issues addressed by the scientific community, such as the hydrogen distribution and storage onboard: Hydrogen Re- fuelling Stations (HRS) and tankers has to fulfil safety criteria not yet consolidated in railway regulations and to manage effectively recharging time constraints. In this context, the present study, developed in cooperation with

Trenitalia (Italian incumbent Railway Undertaking), focuses on two key aspects of the problem. The first is the identification of the existing normative con- straints, at various levels, in the process to produce guidelines for the design of sustainable and harmonized safety rules based on systematic and robust risk analysis approach. The second is the comparative assessment of the present diesel powered operation on the case study of a not electri- fied line in Southern Italy with the radical solution of hydrogen-powered trains, without need of investments on overheads line and with a requirement of 800 km autonomy.

P04.C

Product cost assessment in the early development phase of powertrain systems

Simon Röhrenbacher, Oliver Moerth-Teo, Lukas Schwarz, Hans Schnöll and Christian Ramsauer

In the automotive industry, high competition, volatile markets and short development cycles are commonplace. In addition, the transition to new drive technologies brings further challenges and complexity for car manufacturers. Improved product cost estimation especially during the early development phases enhances design decisions to better address this situation. Due to the lack of data availability in this stage, exact calculations are very difficult and require a lot of experience. Even though various methods to estimate the product cost already exist, they usually vary greatly in accuracy and applicability. Therefore, the focus of this paper is to investigate different qualitative and quantitative product cost estimation methods in the early development phases. First, a literature review provides the fundamental understanding about existing cost estimation methods. Aiming for a data triangulation, documents were collected, experts interviewed and a survey conducted, all at one engineering company dealing with powertrain development. Based on these three sources, two empirical studies were performed (study A: documents and interviews; study B: survey). A subsequent comparison allowed statements about the applicability of qualitative and quantitative cost estimation methods in the early development phases. Finally, two of these methods (case based and fuzzy logic) were applied at two different points in the early stage of battery pack development. In order to represent the increasing data availability when progressing in the development process, different parameters were included. While the reference data for the product cost estimation came from literature, the case company provided the input data for six battery packs of existing electric vehicles. This allowed a comparison of the estimated cost to the actual cost, whereas the calculation of derivations built the basis to evaluate the accuracy of the methods at both points.

P05.A

A more efficient braking system for heavy vehicles

Pontus Fyhr and Leon Henderson

Electric powertrains increase efficiency in road vehicles and enable zero tailpipe emissions, but in- troduce practical limitations in on board energy storage capacity, due to the low energy density in battery systems when compared with chemical fuels in tanks. The increased powertrain efficiency and lower on-board energy storage levels place focus on other energy consumers in the vehicle system, such as the braking system. Our measurements indicate that a conventional pneumatic electronic braking system for heavy vehicles consumes 2-3% of the mission energy in a typical city bus cycle for a battery electric vehicle. The newly developed electromechanical braking sys- tem offers a more efficient energy conversion for the braking function, consuming 0.4-0.7% of the mission energy under similar driving conditions. This work focuses on an energy analysis of the conventional and the novel system in the context of a city bus application. The data is sourced from measurements of a battery electric bus, driven on a proving ground in tests repeated three times, in unladen condition. The measurements include comparative tests for the vehicle equipped with a traditional electro-pneumatic braking system and the same vehicle equipped with the new electro-mechanical braking system.

P05.B

Development of rolling resistance measurement set-up in order to enable energy optimisation of vehicle-road interaction taking into account safety and performance

Lisa Ydrefors, Mattias Hjort, Sogol Kharrazi, Jenny Jerrelind and Annika Stensson Trigell

Reducing the rolling resistance for future vehicle designs creates a possibility to reduce the fuel consumption and make the future vehicles more economical and ecological. For electric vehicles it is also an enabler to increase their driving range per charge. When optimising for reduced rolling resistance, contradictory requirements such as force generation for maintaining safety and performance need to be considered. Furthermore, it is important to include both the effects of road surface and vehicle, to avoid sub-optimisation regarding only the tyres. A cross-functional conflict on the component level is well known, in form of energy consumption versus wet grip (traffic safety). On the system level, different wheel settings to optimise energy consumption conflicts with vehicle dynamical properties related to traffic safety, such as stability or steer response. The long term vision of the work presented is to create tools for more energy efficient vehicles by reducing the rolling resistance during driving. The first part is to establish a credible measurement method for rolling resistance on road under controlled conditions (lab environment). Today's existing measurement methods on rolling resistance under laboratory conditions commonly utilise a rotating drum, whose curved surface affects the results. Therefore, rolling resistance influence of vehicle settings such as camber or toe angles is difficult to assess using standard methods, and there is a need for measurements using a more realistic contact patch, which would need a flat surface. The existing unique tyre testing facility at the Swedish National Road and Transport Research Institute, VTI, is used as a base for developing the new rolling resistance set-up. The tyre test facility is today used to determine tyre characteristics such as brake and steering forces. The method to measure rolling resistance with this equipment under highly controlled conditions is under development, and some preliminary results are presented.

P05.C

Regenerative braking for an electric vehicle with a high-speed drive at the front axle

Ektor Karyotakis, Rémi Mongellaz and Mathias Lidberg

The main contribution of this paper lies in the development of a novel front-to-rear axle brake force distribution strategy for the regenerative braking control of a vehicle with a high-speed electric drive unit at the front axle. The strategy adapts the brake proportioning to provide extended room for energy recuperation of the electric motor when the vehicle drivability and safety requirements permit. In detail, the strategy is adaptive to cornering intensity enabling the range to be further extended in real-world applications. The regenerative braking control features a brake blending control algorithm and a powertrain controller, which are decisive for enhancing the braking performance. Lastly, the regenerative braking control is implemented in the high- fidelity simulation environment Simcenter Amesim, where system efficiency and regenerative brake performance are analysed. Results confirm that the designed regenerative braking greatly improves the effectiveness of energy recuperation for a front-wheel driven electric vehicle with a high-speed drive at the front axle. In conclusion, it is shown that it is feasible to use the high- speed drive with the proposed control design for regenerative braking.

P06.A

Development of a vehicle-road interaction analysis framework for truck tyres

Jukka Hyttinen, Rickard Österlöf, Jenny Jerrelind and Lars Drugge

The current state of global warming requires immediate measures to reduce greenhouse gases and resource efficient vehicles act as a part of the solution. Rolling resistance of truck tyres is one of the main

contributors to the environmental impact of road freight transport. To achieve adequate range for future battery electric trucks, parameters influencing rolling resistance and other tyre properties need to be researched carefully. Tyre manufacturers are able to affect rolling resistance by optimising tyre design, rubber compounds, and by balancing between conflicting properties such as rolling resistance, wear, particulate emissions and grip. Vehicle manufacturers on the other hand can focus on enhancing the optimal usage of the tyre with simulations and testing. The aim of the present work is to develop an FE truck tyre and road modelling framework to be able to quantify and optimise the energy consumption due to rolling resistance and its potential trade- offs with e.g. damaging vehicle forces and road damage. To build an accurate FE truck tyre model, different measurements has been performed to characterise material properties and the tyre structure. Furthermore, a suitable constitutive model is chosen which takes into account amplitude and frequency dependent stiffness and dissipation characteristics. To model the tyre rubber, a parallel rheological framework is used to simulate amplitude and frequency dependency of storage and loss modulus. Currently, there are no simple parametrisation methods and the usage of more advanced constitutive models have a trade-off between tuneable parameters and accuracy. Therefore a simple and robust parametrisation technique for filled rubber with clear and understandable tuneable parameters that can be used in FE tyre simulations is under development. The objective of the tyre model is to enable trade-off evaluations between different properties such as energy consumption and wear of truck components. The ultimate goal is to assess the society-benefit of innovative vehicle chassis and tyre technologies with the developed vehicle- road interaction framework.

P06.B

Possible reduction of energy consumption with single axle running gear

Rickard Persson, Zhendong Liu and Rocco Giossi

Running gears form a significant part of the weight of a railway vehicle, and if the weight of these could be reduced, this would affect the vehicle's energy consumption, especially for services with many stops. In the project RUN2Rail, a part of the EU-funded initiative Shift2Rail, a single axle running gear was proposed for metro vehicles. Active suspensions were suggested to overcome deficiencies in terms of ride comfort and wheelset steering, which are well known for such vehicles. The concept has been further developed in the project NextGear, also part of Shift2Rail, where the material of the running gear frame has been changed from steel to composite to further reduce the weight and the wheelset guidance updated to decrease the running resistance in curves. Prototypes of frame and wheelset steering actuator will be built and tested in the laboratory to validate the performance. The present study is comparing a reference vehicle from Metro Madrid with the proposed vehicle in terms of energy consumption for simulated service on Metro Madrid Line 10 with curvature, gradients, stops and speed profiles considered. Only parameters with relation to the weight, curving performance and auxiliary energy consumption for the active system are assumed different for the vehicles. The vehicles are further assumed to use regenerative braking, hence the energy needed to accelerate the vehicle will be regenerated when braking, but there will be transformation losses with relation to the weight. The simulation results show that the very innovative NextGear vehicles will reduce energy consumption by 8% compared to the reference vehicles. The lower weight and the decreased running resistance in curves contribute about as much to the savings.

P06.C

Cargo bikes - sustainable means of transportation

Saskia Biehl, Heinz Kaufmann, Artur Schönemann, Tobias Melz, William Kaal and Wilfried Kolodziej

Nowadays, mobility in cities is undergoing a visible change. Cargo bikes are becoming a key alternative to cars. They are not only flexible and fast but moreover environmentally- and climate-friendly. Young fami-

lies, craftspeople and delivery services are using cargo bikes and the demand thereof is skyrocketing. This development is particularly favorable, given the climate targets that have been set not only for Germany but worldwide. Therefore, Fraunhofer LBF develops sustainable, comfortable, lightweight solutions for the next generation of cargo bikes. The key aspects of development lie in investigation of a multifunctional frame with integrated sensor and battery systems and mission-depending cargo boxes. As the starting point for these advancements, a commercial cargo bike is used.

P07.A

Potential for CO2 equivalent emission reduction in future passenger car fleet scenarios in Europe

Thu Trang Nguyen, Helmut Brunner, Mario Hirz, Alexander Rust and Johann Bachler

The CO2 emission performance standards (CO2 standards) set limits for fleets of new cars sold in Europe at 95 gCO2/km in 2021 and targeted 59 gCO2/km in 2030. Furthermore, the European Green Deal aims to reduce at least 55% total greenhouse gas (GHG) emissions in the continent by 2030. These legislations will undoubtedly shape future passenger car fleets in Europe. However, the current standards are solely based on Tank-to-Wheel (TTW) analysis, even though other stages of the product life cycle (LC) can contribute significantly to the overall emissions. Therefore, this paper aims at answering the question: what are possible GHG emission reduction potentials, measured by CO2 equivalent (CO2eq), over the whole LC of future EU-wide passenger car fleets that meet the CO2 standards? Firstly, LC CO2eq emissions of several state-of-the-art propulsion systems are examined. The technologies considered are internal combustion engine, battery electric, hybrid, plug-in hybrid and fuel-cell. Data on CO2eq emissions in different LC stages are identified via literature review and own calculations. Reduction potentials of the technologies are addressed for three scenarios, namely 2020 as a basis, 2030, and 2050. Secondly, fleet configurations are defined for the years 2020 and 2030 in order to meet the CO2 standards, by considering specific TTW CO2 emissions of the technologies and their shares in the EU passenger car fleet. Finally, LC CO2eq emissions of possible future fleets are calculated. The results indicate that only increasing the number of low emission vehicles entering the fleet until 2050 will not be sufficient to achieve the transport GHG emission targets. Other measures such as technology improvements, renewable-based electricity grid and e-fuels, need to be taken into account as well. Moreover, TTW-based analysis does not reflect the whole sectoral emissions, thus Well-to-Wheel or even LC emissions should be considered in legislations.

P07.B

A preliminary investigation of robust design and uncertainty quantification within the life cycle energy optimisation methodology

Hamza Bouchouireb, Ciarán J. O'Reilly and Peter Göransson

The Life Cycle Energy Optimisation (LCEO) methodology aims at finding a design solution that uses a minimum amount of cumulative energy demand over the different phases of the vehicle's life cycle, while complying with a set of functional constraints. This effectively balances trade-offs, and therewith avoids sub-optimal shifting between the energy demand for the cradle- to-production of materials, operation of the vehicle, and end-of-life phases. The present work describes the inclusion of robust design aspects and uncertainty quantification into the LCEO framework. In particular, uncertainty is introduced through the assumption that the material and energy properties of a subset of the optimisation's candidate materials are described by statistical distributions as opposed to a priori fixed values. Subsequently, the nature of the LCEO-associated optimisation problem is changed from deterministic to stochastic. This change is handled by defining a multilevel representation hierarchy, and using the Multilevel Monte Carlo (MLMC) approach in the optimisation process to evaluate the expected compliance of a given design with the transport-related functional requirements. The extended framework is applied to the robust design opti-

misation of a subsystem of a vehicle model which is both mechanically and geometrically constrained. The ability of the LCEO methodology to include robust design aspects early during the vehicle design process, while simultaneously handling functional conflicts, to result in a robust life cycle energy optimal design is demonstrated. Furthermore, the performance increase obtained by the use of the MLMC approach instead of the classical Monte Carlo approach within an optimisation under uncertainty framework is illustrated.

P07.C

Life cycle assessment of distribution vehicles: Battery electric vs diesel driven

Dora Burul and David Algesten

Scania's purpose is to drive the shift towards a sustainable transport system. A holistic view is key both to support our customers' business as well as addressing environmental impacts. Life Cycle Assessment (LCA) is an ISO 14040/44 method to calculate the environmental impacts of products or services over their entire life cycle: in this case the vehicle and battery production, use, maintenance and recovery.

LCA in Scania is used to evaluate the product's environmental impacts and setting internal project targets in product development. Scania has built up in-house capacity and competence to conduct LCA and guides the organisation via LCA as a fact base. With this external LCA publication Scania takes a step further to inform stakeholders of key LCA findings.

Scania is in the middle of a transformation with already connected, more electrified and arising autonomous products and services. For Scania's product development this means more than producing a few electrified vehicles – a complete modular toolbox is needed to offer the great variety of commercial vehicles also as electrified. Scania's first fully serial produced BEV was launched during the autumn of 2020. This made the choice easy to conduct this first publicly available LCA as a comparison between a representative distribution BEV, available in the first launch, with a corresponding ICEV.

The study covers the entire vehicle life cycle from cradle to grave, starting at the extracting and refining of raw materials and ending at the recovery of the vehicles. The chosen functional unit has the aim to reflect and represent a full life of operation for the vehicles. The functional unit is: 500 000 km driven in a representative distribution cycle with an average payload of 6,1 ton.

The vehicle technical properties, besides the drive trains, are kept as similar as possible to make the comparison as fair as possible. The installed battery capacity in the BEV is 300kWh. European grid mix with reference year 2016 is used as the baseline for the carbon intensity in the electricity used in the BEV. Additional grid mixes have been investigated to analyse the impact from future prognoses mixes as well as green electricity. The fuel used for the ICEV is B7 diesel with 7% RME drop-in, representative for European conditions. The production of the BEV entails a higher environmental impact, mainly due to energy intensive battery cell manufacturing. GHG emission raises from 27,5 tonnes CO2eq (ICEV production) to 53,6 tonnes CO2eq (BEV production). GHG emissions coming from production of battery cells are 74kg CO2eq/kWh of installed battery capacity. Despite the increased production burden, the total life cycle impact on climate change shows a dramatic reduction potential for the BEV, thanks to the much lower impact from the use phase. Depending on the carbon intensity in the EU electrical grid, the life cycle GHG reduction spans from 38% (EU mix 2016) to 63% (prognoses EU mix 2030). Powering the vehicle with green electricity is the way to fully utilise the potential with the BEV. The results show a life cycle GHG reduction of 86%.

Due to the higher GHG emissions from the production, BEV vehicles can be seen as having a carbon debt in comparison to ICEV. The GHG debt will somewhere in time be repaid due to the lower use phase emissions per km. This is usually called the break-even point, the point in time when the BEV starts having a smaller total GHG impact than the ICEV. Depending on the carbon intensity, the break-even occurs between 33 000 km (green electricity) to 68 000 km (baseline 2016). This indicates that the BEV has the potential to have less climate impact than the ICEV already within one or two years of operation, for all investigated electricity mixes in the report.

At the End-of-Life Scania traction batteries are collected, dismantled, shredded and recycled by collection and recycling partners. The exact recycling process depends on geographical location and partner

setup. Due to the varying market setups (pilot vs large scale recovery) and limited relevant data, the choice has been to exclude the battery recycling from the recovery model. Further, no second life of the battery is assumed in the LCA model, meaning that the full production burden is attributed to the Scania vehicle's life cycle. There is also a dramatic reduction potential for other impact categories like fine particle formation, ozone creation and terrestrial acidification. The reduction in these categories lies between 83-97%, mainly due to eliminating tailpipe emissions.

Fossil resource use and eutrophication of marine- and freshwater also decrease significantly (18-48%) for the BEV, even though there are a considerable impact related primarily to coal in the electricity generation. The main reason is that well-to-tank impact from diesel production is higher than the impact coming from electricity generation.

This LCA gives a view of the magnitude and relationship between environmental impacts for the BEV and the ICEV distribution trucks. However, the LCA results, especially in absolute terms are not intended to be compared to other OEMs. The choice of functional unit, methodology, scope and access to primary data will have a great influence on the final result.

All facts and figures in this report are third party verified in a background report (Scania internal). The verification was done by IVL Svenska Miljöinstitutet following the ISO 14040/44 standard.

P08.A

System-wide impact of vehicle innovations – Evaluating Track-friendliness during vehicle design

Carlos Casanueva, Visakh V Krishna and Sebastian Stichel

The cost of maintenance of railway tracks due to vehicle passage is a major limiting factor to the competitiveness of railway sector in EU. For instance, in Sweden in 2017 only, 2800 million SEK was spent on track maintenance and reinvestment due to wear and tear caused by traffic. Considering this, there is a major incentive to operate track-friendly vehicles that also facilitate economically feasible maintenance strategies. In this context, the NEXTGEAR project aims to incorporate a track-friendliness module in the 'Universal Cost Model 2.0' that can estimate operating costs for a given set of operational parameters such as vehicle suspension design, energy usage, track geometry, etc. Such a tool could be useful in estimating the costs for a train operator for a given route and application. However, estimation of costs due to track damage is a complex cross-disciplinary task encompassing varying domains such as vehicle dynamics, tribology, economics, maintenance policy etc so that actual damage in the infrastructure can be linked to maintenance actions and thus costs. Currently there are two major diametrical approaches such as the 'Bottom-up' Engineering approach that seeks to create accurate engineering models of vehicle, track, etc. Then there is the 'Top-down' Econometric approach that seeks to create statistical models linking the operating variables with historically recorded cost data. Also, track damage itself manifests in various forms such as wear RCF and settlement and it is extremely useful to understand the distribution of costs amongst them. Nowadays a Hybrid approach is being developed that can bridge the limitations of the other two methods. Eventually all these models seek to calculate differential operating costs due to the introduction of vehicle innovations during the design stage, hence contributing to the overall economic feasibility of the railway system.

P08.B

A life cycle energy and weight comparison of a carbon fiber composite versus metallic component in a commercial vehicle

Sara Eliasson, Mathilda K. Hagnell, Robert Jonsson, Per Wennhage and Zuheir Barsoum

Lightweight design is important for Battery Electric Vehicles (BEVs), to minimize the effects from the added weight of the batteries. The study looks at the benefits and disadvantages of choosing a Carbon

Fiber Reinforced Polymer (CFRP) material in comparison to metallic ma- terial for a specific battery electric commercial vehicle component. A Life Cycle Energy (LCE) and weight analysis are the basis for the comparison. Other aspects that could be considered im- portant for the industrial implementation, such as cost, are also discussed. The LCE is assessed using a combination of engineering process modelling, available data from industrial partners, and data available in the literature. The analysis is aimed to support a holistic comparison, which means the modelling is performed on an overarching level of detail.

P08.C

The environmental benefits and challenges of the composite car with structural battery materials

Frida Hermansson, Ivan Berg, Kevin Sandberg, Leif E. Asp, Matty Janssen and Magdalena Svanström

One way to reduce the environmental impact of an electric vehicle is to reduce the vehicle's mass. This can be done by substitution of conventional materials such as steel, aluminium, and plastics with carbon fibre composites, or possibly even with structural battery composite materials. In the latter case, another consequence is that the size of the vehicle battery is reduced as the structural battery composite not only provides structural integrity, but also stores energy. This study assesses the change in life cycle environmental impacts related to transitioning from a conventional battery electric vehicle to a vehicle with components made from either carbon fibre composites or structural battery composites, with the aim of identifying environmental challenges and opportunities for cars with a high share of composite materials. Results show that a transition to carbon fibre composites and structural battery composite materials today would (in most cases) increase the total environmental impact due to the energy intensive materials production processes. The two major contributors to the environmental impacts for the structural battery composite materials are energy intensive structural battery material manufacturing process and carbon fibre production process, both of which can be expected to decrease their energy consumption as the technology maturity level increases and other production and manufacturing processes are developed. For future assessments, more effort needs to be put on collecting primary data for large-scale structural battery composites production and on assessing different technology development routes.

P09.A

Green chips urethane based poroelastic materials: An opportunity for up to 80% recycled and 100% recyclable content coming from recycled PU mattresses

Arnaud Duval, Guillaume Crignon, Maxime Roux and Dominique Lemaire

Chips urethane porous materials usage is known in the automotive industry as spacer function mainly or stiff porous barriers in hybrid stiff insulators, using both resin based or thermoplastic based binders, with injected foam as poroelastic spring traditionally. The switch from thermoset resin binders to thermoplastic PET bi-component fibers makes the material 100 % recyclable and improves drastically the poroelastic spring vibro-acoustic properties. Indeed, hybrid stiff insulators or under carpet insulators are thus feasible with 100 % usage of this thermoplastic chips urethane based recycled material called Polyfoam T used for both stiff absorbing barriers and poroelastic spring functions. Transformed in one shot processes, these innovative hybrid stiff insulators presents excellent mechanical decoupling properties even at high densities above 150 kg/m3 and up to 300 kg/m3 typically. This is particularly interesting in these one shot thermoforming processes where low thickness areas may exist due to complex package management (available space) in the automo- tive industry. As these low thickness areas are the poorest performing areas of the insulators, a Transmission Loss improvement of more than 7 dB in average compared to traditional

porous injected or thermoformed materials improves drastically the insulator performance allowing further weight reduction while keeping the recyclability advantage even for the End of Life Vehicles phase.

P09.B

Periodic resonator-based optimization of an acoustic package made of glass wool

Giuseppe Catapane, Dario Magliacano, Giuseppe Petrone, Francesco Franco and Sergio De Rosa

Nowadays, modern urbanization and traffic increase could cause severe noise-induced health dam- ages, such as annoyance, sleep disturbance, or even ischemic heart disease, and thus the interest on environment noise control is quickly growing. Unfortunately, a sound absorbing material that well performs in overall the frequency range is not present in nature. For instance, acoustic solutions such as Helmholtz resonators have good performances at low frequencies, while porous media, whose foam cavities dissipate the energy by viscous and thermal losses, perform better at high frequencies. The scope of this work is to investigate the sound transmission loss of an acoustic package made of glass wool, as well as to propose innovative solutions based on the inclusion of a periodic pattern of Helmholtz resonators inside its core, aiming at passively improving the acoustic performance in a chosen range of frequencies. In order to reach this goal, a numerical model is studied, and the effect of Helmholtz resonators tuned at several frequencies are simulated. For each of these layouts, also the mass increase of the so-called meta-core, compared to that of its classical homo- geneous counterpart, is estimated. Results obtained herein may constitute a good basis in order to perform preliminary design considerations that could be interesting for further generalizations.

P09.C

3D tunable anisotropic metamaterial for low-frequency vibration absorption

Huina Mao, Romain Rumpler and Peter Göransson

In the well-known conflict between design space and performance requirements e.g. in terms of noise and vibration insulation, the emergence of new materials exhibiting exceptional insula- tion properties for a reduced weight or volume increase has received much attention in the last decade. Metamaterials with artificially designed architectures are increasingly considered as new functional materials with unusual properties. This paper presents a group of novel 3D lattice metamaterials for low-frequency vibration absorption. The novel lightweight cellular microstruc- tures for vibro-acoustic metamaterials are designed by modification of the Kelvin cell. Interesting anisotropic material properties are generated by controlling the geometries, e.g., high-stiffness, auxetic, and strong compression-torsional coupling properties. The interesting meta-properties enable to tune the cellular resonators of the structures at a low-frequency range. Previous research is mostly focused on metamaterials for vibration absorption along only one or two directions. In this paper, wide-band high sound absorption properties of energy transfer coupling in all three directions are achieved by tunning the frequency-dependent meta-structures in controlling the geometry and material properties. Additive manufacturing technologies are used for making the 3D complex tunable metamaterials.

P10.A

Analytical method for predicting micro-geometry-based flow resistivity in anisotropic foams to improve sound absorption of vehicle panels

Eva Lundberg, B. P. Semeniuk, Huina Mao, Romain Rumpler and Peter Göransson

Vehicle structures such as train floors or car roofs are usually built as multi-layer panels, where a foam is placed between a load-carrying structure and an interior panel. The foam adds acoustical and thermal per-

formance, but very little weight. In most contributions introducing foams for acoustic treatment, these have been considered isotropic, with acoustic losses mainly depending on properties in the thickness direction. Another mechanism investigated here is the possibility for the acoustic flow in the foam to change from acting only in the thickness direction but rather to be re-directed to also travel in-plane, where dimensions are substantially larger than in the thickness direction, permitting more losses as the wave travels through the material. That kind of effect would result in higher acoustic losses without increasing the thickness of the vehicle panel and better use of the allowable space to achieve acoustic and functional requirements, i.e. a better functional density. A first step is to investigate how the absorption properties of an anisotropic foam differs from an isotropic foam. The chosen approach is to use an analytical micro-model to calculate the dynamic drag impedance (flow resistivity on micro-scale) for an anisotropic open cell foam material. Based on a simple micro-scale geometry of Kelvin cells, it has been shown that simple cell alterations to the micro-geometry, such as stretching, twisting and tilting results in an anisotropic foam structure. The anisotropic flow resistivity tensor is not diagonal and uniform, but different directions can have different magnitudes and it can display off-diagonal coupling terms. The influence of such micro-scale distortions on the flow resistivity, and on the resulting sound absorption is investigated with the purpose of improving the acoustic performance without adding volume. Future steps include to modify the functional density and tailor the sound transmission loss to a specific application.

P10.B

Optimization of deep drawing process parameters for multiple functional requirements

V. K. Balla, E. Deckers, B. Pluymers, J. Stroobants, H. G. Sakinala and W. Desmet

In this work, a cylindrical cup design is investigated for meeting the dimensional accuracy, vibro- acoustic and crash performance simultaneously. Cylindrical cup forming simulations are per- formed using different deep drawing process parameters—Blank Holder Force (BHF), Friction Coefficient, Blank thickness and misalignment—to predict geometric profile and thickness vari- ations. The formed geometry is used to simulate the vibro-acoustics performance of the design. The cylindrical cup has nominal dimensions of 80 mm diameter, 24 mm deep and 0.97 mm thick- ness. Forming simulations are performed to quantify the vibro-acoustic variability caused by changes in process parameters. The vibro-acoustic variability is attributed to the geometry profile and thickness distribution changes of the deep drawing manufacturing process. To investigate the same, the Design Of Experiments (DOE) studies, based on Taguchi orthogonal arrays, are carried out to characterize the effect of individual process parameters on the response. The deep drawing analysis and the subsequent vibro-acoustic simulations are instrumental in optimizing both functional requirements. The crash performance of the component is predicted using the empirical formula mentioned in the literature. It is shown that a careful selection of process parameters help to optimize the response for multiple functional requirements.

P10.C

Systematic design of a generic Life Cycle Assessment model construct for aluminum automotive components

Patrick Haun, Philipp Müller and Marzia Traverso

With increasing awareness on environmental issues, there is a necessity to make the environmental performance of a product assessable. The most valid and scientifically recognized methodology to achieve this target is the Life Cycle Assessment (LCA). In the automotive industry, the carbon footprint is the main focus when it comes to the environmental performance. A vehicle consists of many components. This makes an overall LCA of a vehicle a complex project, which cannot be done without the support of databases and software tools. One possibility to handle the complexity is the assignment of components to pre-defined Life Cycle Inventory (LCI) models based on secondary data, which can lead to inaccuracies if

the assignment is not done by the most influencing component attributes. This paper tackles the conflict of inaccuracy and modelling effort of the automated LCAs with assigned LCI models. A methodology to build a construct of generic LCI models under constraints regarding accuracy and modelling effort is here presented and discussed throughout an example. For this approach, the relevant factors influencing the Global Warming Potential (GWP) of the component have to be identified. A distinction has to be made as to whether the influencing factors are described by discrete or continuously variable parameters. Considering the constraints on accuracy and modelling effort, the parameters have to be discretized and grouped to meaningful grid points. The number of grid points can be reduced when technical constraints are considered. The method is applied on the cradle-to-gate modelling of aluminium automotive components for the main technologies casting, deep-drawn sheets and extrusion. Due to a systematic construct of pre-defined LCI models, the assignment of LCI models is more flexible and the effect of the most relevant component attributes on the GWP are observable.

P11.A

Concept of a digital product passport for an electric vehicle battery

Katharina Berger, Josef-Peter Schöggl and Rupert J. Baumgartner

The concept of circular economy (CE) has recently gained momentum due to being perceived as a potential facilitator of sustainable development. In the context of electric vehicles, it is argued that the value chain (VC) of an electric vehicle battery (EVB) would benefit from transitioning from a linear to a circular one due to the potential of the latter one to reduce environmental pressures and enhance the security of supply of raw materials. However, VC loop-closing pathways may not necessarily contribute to enhanced VC sustainability performance. Information technologies such as the digital twin (DT) could be used to support VC stakeholders in identifying sustainable loop- closing pathways. The DT technology has recently received attention because it is perceived as a potential technology for driving so-called “digital product passport”. The idea of such ap- plications is currently being discussed due to their potential to function as unique identifiers of their corresponding physical counterparts by containing specific product/material-related data and gathering real-time data over the entire life cycle of a product. Such an application could support value chain stakeholders in their efforts to manage the sustainable circularity on the product level. In this context, this study provides a preliminary concept of the information model of an EVB’s digital product passport. This information model details data types, sources, and requirements for different use cases of sustainable and circular battery management. Conducting a dynamic life cycle assessment of an EVB or deciding on an EVB’s potential second life serve as examples of such use cases. The findings stem from conducting a systematic literature review, as well as a preliminary model validation by three industry experts. In summary, the preliminary conceptual information model presented shall provide a first building block for a comprehensive EVB digital product passport concept.

P11.B

A generic approach to capitalize manufacturing experience in design and optimization

Philip Eyckens, Frank Naets, Elke Deckers, Eveline Rosseel, Hendrik Schuette, Ioanna Koutla, Reginald Diltoer, Carlos Lopez and Pierre Duysinx

As design changes in the production phase can be hundreds of times more costly than in the design phase, it is crucial to make sure that the designed product is actually manufacturable before start of production. To this aim nowadays often many manual iterations are needed between the designers and manufacturing experts, which leads to an inefficient design process and delayed time-to-market that in turn are detrimental for company competitiveness. Here we present the outline of a research effort to realize a substantially more integrated design process tailored towards both performance aspects and manufacturability. Key to this is the formalisation of Design for Manufacturing (DfM) rules within the functional CAD design stage. The traditional design approach is exemplified further in this work for the design of a gearbox housing for

electric vehicle transmission systems. To realize substantial weight reduction without compromising performance, a novel multi-material design is proposed, constituting of both aluminium, to ensure structural integrity, and high performance polymer for additional structural integrity and leak-tightness under operating condition. Results shown include Topology Optimization (TO) under realistic loading conditions, scrutinizing material volume fraction boundary conditions and mesh sensitivity. Finally, some DfM rules and considerations in order to come to a manufacturable CAD design, are highlighted.

P11.C

Validation of a novel XiL setup for frontloaded testing of an electric vehicle powertrain

Bart Forrier, Thomas D'hondt, Leonardo Cecconi and Mathieu Sarrazin

The importance of electric vehicles to the automotive market continues to increase. Meanwhile, the demand for high levels of energy efficiency, performance and comfort leads to ever more integrated E-powertrains and sophisticated controllers. This complicates the vehicle development process and raises the need for frontloaded testing. Model based approaches, such as Hardware-in- the-Loop (HiL) tests, address this need. However, they approximate operational full-vehicle tests, rather than to replace them, and their performance assessments may be biased. This work focuses on an E-powertrain subsystem, consisting of its traction motor with inverter and controllers. The frontloaded assessment of this subsystem's in-vehicle performance is done on a new X-in-the- loop setup. In HiL mode, the real subsystem under test is coupled to an executable digital twin of the vehicle. The main contribution of this paper is that it provides a quantitative validation of the obtained HiL test results. The evaluation is made primarily in terms of energy consumption. The reference dataset is obtained in a full-vehicle on-road operational test campaign. The in-lab HiL test results correlate well with on-road full-vehicle operation. Their validated accuracy is also related to the use of HiL based explorative test results. This is done by studying the effect of design changes, e.g. a modified gearbox ratio or battery pack, on the energy consumption.

P12.A

A methodology to assess the impact of driving noise from individual vehicles in an urban environment

Sacha Baclet, Siddharth Venkataraman and Romain Rumpler

Road traffic is a major source of environmental noise pollution in urban areas, while the intra-day distribution of road traffic is often leading to sub-optimal use of infrastructure and ressources. In order to evaluate and enable improved distribution of traffic, taking into consideration its im- pact in terms of noise emissions and other externalities, the present contribution focuses on a methodology designed to assess the impact of the noise generated by individual vehicles on a city's population using NoiseModelling, an open-source library implementing the CNOSSOS-EU model, capable of producing environmental noise maps. The method was applied to delivery trucks in the city of Stockholm, comparing the population's exposure in a variety of scenarios. The initial step consists in processing microscopic traffic data (simulated in the present contribution), where the traffic intensity is dependent on the time of day that is targeted. The micro-traffic data is subsequently used to generate background noise maps by simulating the propagation of traffic noise using NoiseModelling. Then, the impact of the noise from the vehicle of interest is simulated, based on several parameters (route followed, type of motorization: diesel or hybrid, etc.). Finally, the data is post-processed to calculate the "exceedance" (increase in ambient noise) caused by the vehicle, taking the previously calculated background noise maps as reference. The complete methodology, its underlying assumptions, and the associated criteria proposed in order to assess the impact of noise emissions from individual vehicles will be presented and demon- strated on realistic scenarios.

P12.B

Analyzing interaction effects in a vehicle model using network theory

Sai Kausik Abburu, Carlos Casanueva Perez and Ciarán O'Reilly

The vehicle industry is moving towards developing more sustainable and efficient solutions. This movement towards sustainable and efficient solutions brings up the need to develop and inte- grate new subsystem technologies that are beneficial for the overall vehicle system. However, introducing new technology into an existing vehicle architecture may have knock-on effects on the dependent subsystems. Furthermore, there can be a bias towards the existing technological solutions as a large part of the architecture is developed pertaining to the established solutions. Therefore, sufficient knowledge is required to understand the level of impact the interdependencies, both direct and indirect, can have at a subsystem level and at the overall vehicle system level. To address and assess these interdependencies that arise during the conceptual design phase, a bottom-up design model is proposed. The model, utilizing network theory could represent each subsystem as nodes and their interaction effects on each other as edges. Thus, the interaction effects between different subsystems and their complex influence on the overall vehicle system are considered. This model could serve to evaluate an optimal solution in terms of functional density and economic benefits thus providing the opportunity to avoid any unintended negative indirect effects. Furthermore, it could help in identifying the technological limits in the current vehicle system and thus, identifying the areas that can be developed to further enhance the vehicle system performance. The method of implementation, its advantages, disadvantages, applications, and challenges in implementation are discussed.

P12.C

Open-source modeling chain for the dynamic assessment of road traffic noise exposure

Valentin Lebescond, Arnaud Can, Pierre Aumond and Pascal Gastineau

In light of the growing concern about the adverse effects of noise pollution on health, a better understanding is needed of the relationships between urban transport and individual exposure. To improve the scientific community's modelling capabilities specific to this issue, we are proposing a noise exposure modelling framework that uses agent-based activity, multi-agent travel simu- lation and a European standardized noise emission and propagation model. Based on two open source software packages, MATSim and NoiseModelling, this framework aims to simulate the spatiotemporal distributions of daily individual activity and road traffic noise. As such, it enables both characterizing the individual exposure to road traffic-related noise and investigating noise exposure inequality problems based on the attributes of individuals and their activities.

P13.A

Using Analytical Hierarchy Process (AHP) to introduce weights to Social Life Cycle Assessment of Mobility Services

Katharina Gompf, Marzia Traverso and Jörg Hetterich

Decisions in sustainability assessment of mobility services and in particular in social sustainability, often pose a multi-criteria decision making issue, as trade-offs can occur between multiple alternatives and a participatory process should be used. Thus, the goal of this research is to support decision-making through determining weightings for different criteria and indicators within the five stakeholder groups presented by the UNEP/SETAC Guidelines and by implementing a participatory process. The selected indicators to be weighted were adopted from Gompf et al. (2020), who conducted an intensive literature review and suggested for the first time a holistic set of indicators for the evaluation of mobility services. The analytical hierarchy process (AHP) method was used to determine weightings for the chosen indicators. A participatory analysis has been used to identify those weightings. In total, 48 experts in the field of sus-

tainable urban mobility were questioned for the weighting process. These experts were chosen from three different groups: academic institutions, city authorities and mobility service providers in order to be able to analyse differences as well as similarities between these groups. While some indicators resulted in clear prioritization, other indicators revealed large differences between the expert groups. For the majority of indicators, the weighting results are similar for all three groups of experts. Consequently, the results provide clear guidance for decision makers in the field of sustainable urban mobility. Further research should consider expanding the sample size, the geographical scope as well as investigating whether additional expert groups in the area of sustainable urban mobility should be included in the weighting process.

P13.B

An initial exploration of measures of transport efficiency through optimising a simple truck model

Khashayar Shahrezaei, Ciarán O'Reilly, Timo Lähivaara and Peter Göransson

Sustainability has become a very important research area in transportation where demands and associated environmental impacts have been increasing. An introductory exploration is established here, where transport efficiency is studied in two partial measures, mass efficiency and volume efficiency. An optimisation problem is then formulated here to find an acceptable design configuration that merely satisfies the transport constraints and maximising transport efficiency. It is observed that there are trade-offs between environmental impacts in terms of energy requirement and the optimised design configuration.

P13.C

Towards a multi-scale and multi-domain modelling of road cargo systems

Per-Olof Sturesson and Stefan Edlund

The introduction of new technologies such as internet of things (IoT), autonomous driving (AD) and new propulsion system technologies, i.e. electrification, opens new perspectives of concept evaluation and selection. These challenge any form of optimization in the product development of future road cargo systems. In the early phase of product development data uncertainty, which is related to design degrees of freedom, is high. The difficulty in the mathematical modelling of road vehicle cargo systems in the concept phase lies in the definition of the principal parameters and their relations that captures the key questions to be answered in the product development decision process from i.e. a business and sustainability perspective. In a radical technological change and when introducing additional domains to the vehicle like general infrastructure and IoT services in the model, the outcome may be different as well as the engineering challenges. This paper focuses on the definition of a general framework for modelling of road vehicle cargo systems using a multi-scale and modelling approach and provides an outlook for future studies.

P13.D

On the trade-off between noise exposure cost and resource efficiency in traffic

Johan Nygren, Susann Boij, Romain Rumpler and Ciarán J. O'Reilly

Achieving sustainable transport involves a trade-off between providing transportation while reducing traffic-related impact, such as improving resource efficiency and reducing the noise exposure. Previous studies showed that the trade-off between reducing the noise exposure cost and reducing the energy demand is dependent on other factors than the vehicle itself. Being part of traffic in a road network, the interactions between other vehicles will affect both the necessary mechanical work associated with the motion of the vehicle, the energy demand, and the result- ing noise exposure cost due to the noise emissions from each vehicle in the traffic flow and the vehicles' locations with respect to the measurement points in the net-

work at which the noise expo- sure is evaluated. While initial results of microscopic traffic simulations indicate that a vehicle's energy demand and noise exposure cost are positively correlated, it is also shown that the vehicle- specific noise exposure cost does not correlate with the increase in system-wide noise exposure costs under peak traffic conditions. For vehicles travelling in the network during peak hours, this means that a reduction in the vehicle-specific noise exposure cost may not necessarily correspond to a lower rate-of-change for the system-wide noise exposure cost. A different allocation strategy may improve the correlation between the vehicle-specific noise exposure cost and the system-wide effects. The study aims to analyse the correlation between different vehicle-specific effects and system-wide effects in a microscopic traffic simulation. It also aims to analyse how a weighting-based allocation strategy for the vehicle-specific noise exposure cost affects the correlation between the vehicle-specific noise exposure cost and the rate of change of the system-wide noise exposure cost, and how this allocation strategy in turn influences the correlation between the energy demand and the vehicle-specific noise exposure cost.