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CONFERENCE REPORT: 66TH DISCUSSION FORUM ON LCA

LCA of mobility solutions: approaches and findings—66th LCA forum, Swiss Federal Institute of Technology, Zurich, 30 August, 2017

Rolf Frischknecht[1] · Christian Bauer[2] · Andreas Froemelt[3] · Stefanie Hellweg[3] · Kirsten Biemann[4] · Thomas Buetler[5] · Brian Cox[2] · Peter de Haan[6] · Sebastian Hoerl[3] · René Itten[7] · Niels Jungbluth[8] · Yorick Ligen[9] · Nicole A. Mathys[10] · Samuel Schiess[11] · Salome Schori[12] · Patricia van Loon[13] · Jing Wang[3] · Sarah Wettstein[14]

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1 Introduction and overview

Due to the Diesel scandal related to NO_X exhaust emissions and the continuously increasing gap between test cycle and real life fuel consumption, the search for environmentally benign individual mobility options is being intensified. In the past recent years, life cycle inventory data on transport services have been updated and life cycle assessment (LCA) is being used to assess the environmental impacts of electric cars and mobility scenarios. The 66th LCA forum on mobility provided an overview on the state-of-art of knowledge, modelling and data in the transport sector.

2 Transport outlook 2040 for Switzerland

Nicole A. Mathys (Federal Office for Spatial Development ARE and University of Neuchâtel, Switzerland) opened the LCA forum with presenting the transport Outlook 2040 for Switzerland. The Federal Office for Spatial Development ARE calculated how transport in Switzerland will develop in the decades to come. The findings—in the form of "if-then" scenarios for passenger and freight terrestrial transport (road, rail, pedestrian and cycling)—serve as a basis for planning road and rail infrastructure programmes, transport and spatial planning policy decisions, the Energy Outlook and noise and air emission calculations. Transport will continue to increase over the decades to come, albeit at a slower rate compared with the past 20 years. Results are summarised in Fig. 1. Continued population and economic growth will be offset by the approaching saturation in the level of mobility tool ownership and the number of trips per person. Although pensioners are becoming increasingly active, the share of the highly mobile working population is declining. The freight transport intensity will continue to fall, because more valuable and lighter goods will be transported. In addition, the service sector is expanding more rapidly than the rest of the economy, while transport-intensive sectors are growing more slowly.

Responsible editor: Mary Ann Curran

✉ Rolf Frischknecht
frischknecht@treeze.ch

[1] treeze Ltd., 8610 Uster, Switzerland

[2] Paul Scherrer Institute PSI, 5232 Villigen, Switzerland

[3] ETH Zurich, 8093 Zurich, Switzerland

[4] ifeu–Institute for Energy and Environmental Research Heidelberg GmbH, 69121 Heidelberg, Germany

[5] empa, 8600 Dübendorf, Switzerland

[6] Ernst Basler + Partner AG, 8702 Zollikon, Switzerland

[7] ZHAW School of Life Sciences and Facility Management, Institute of Natural Resource Sciences, 8820 Wädenswil, Switzerland

[8] ESU-services Limited, 8200 Schaffhausen, Switzerland

[9] EPFL Valais Wallis, 1951 Sion, Switzerland

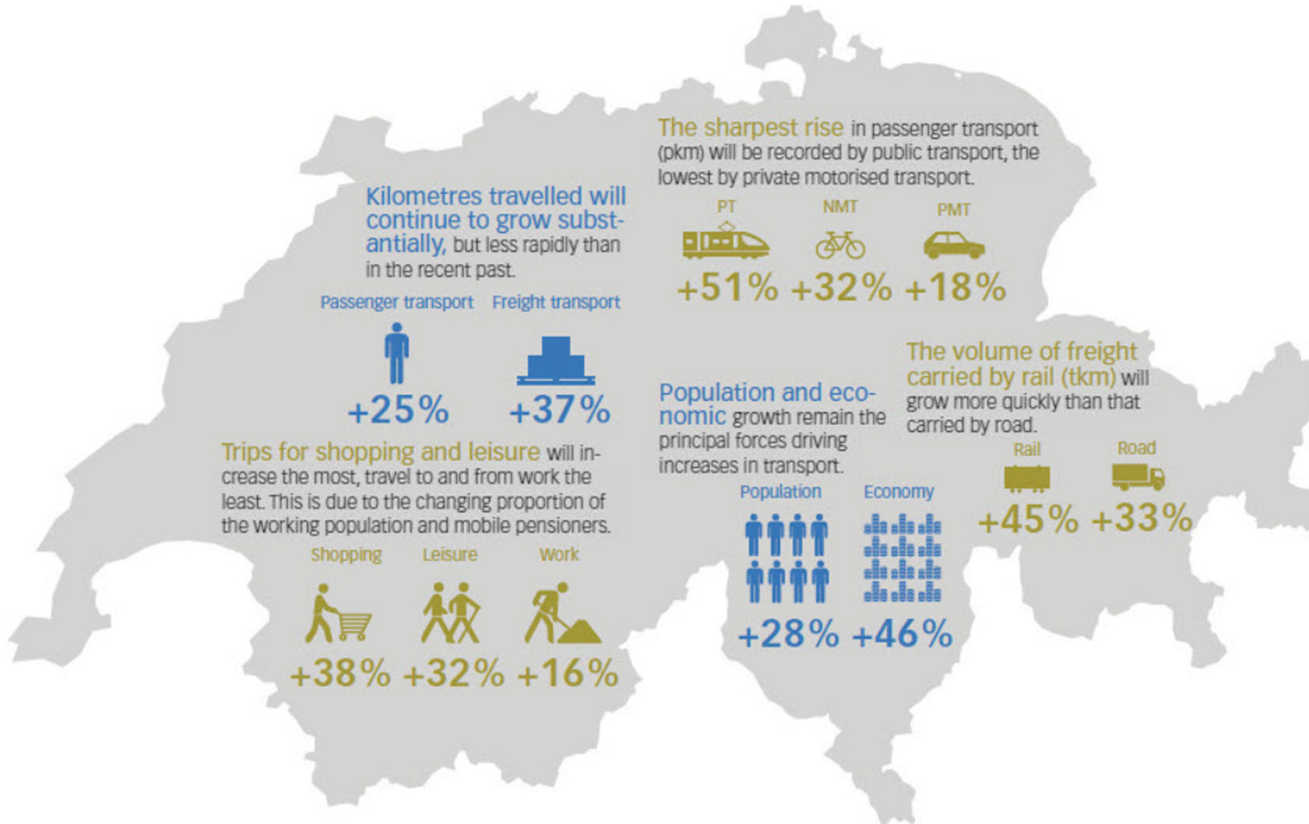
[10] Bundesamt für Raumentwicklung ARE, 3003 Bern, Switzerland

[11] Bluewin, Zurich, Switzerland

[12] SBB, 3000 Bern, Switzerland

[13] RISE Viktoria, 417 56 Göteborg, Sweden

[14] ZHAW Life Sciences und Facility Management, 8820 Wädenswil, Switzerland



Transport Outlook 2040: Overview of the trend in key indicators between 2010 and 2040 (reference scenario).

Fig. 1 Main results in percent changes of key elements of Swiss mobility from 2010 to 2040

Hence, there are indications of a modest decoupling of structural growth and the expansion in transport.

3 Recent development in mobility related LCI data

Rolf Frischknecht (treeze Ltd., Switzerland) presented the main elements of the update and extension of the life cycle inventory data on transport services. The scope covered manufacture, operation and end-of-life treatment of transport equipment including infrastructures such as roads, railways and airports. The focus of the data update was on fuel demand and emissions during operation (including noise), as well as on load and utilisation factors. The data were prepared according to the ecoinvent quality guidelines v2 and are embedded in the KBOB LCA data DQR v2:2016 (KBOB et al. 2016). Passenger car fuel consumption was determined based on real life data. Along with the update of passenger cars life cycle inventories (LCI), inventory data on oil production in Azerbaijan, Kazakhstan, USA and Mexico were established. Rail transport data cover several national railway companies including their specific electricity mixes. Air transport LCI data of economy, business and first class passengers were established. The allocation between passengers and freight is based on weight, using a passenger related weight of about 160 kg, based on the methodology of the International Civil Aviation Organization ICAO. The enhanced climate change effects of airplane emissions (contrails and water vapour) is taken into account with a 35% increase of the global warming potential of CO_2 emitted by airplanes. The updated data are used by mobitool.ch, a Swiss platform for mobility solutions as well as in the Swiss ordonnance of the energy label of new passenger cars.

Brian Cox (Paul Scherrer Institute, Switzerland) presented the results of analysing the impacts of different future electricity scenarios on prospective LCA results for battery electric vehicles. The main effort of this work was the use of the Wurst software (Mutel and Cox 2017) to create future versions of the ecoinvent database (Wernet et al. 2016) to use for the analysis. Electricity sector results from the IMAGE integrated assessment model (Stehfest et al. 2014) were used to modify the efficiency and direct emissions of all fossil, biomass and nuclear electricity generation activities and the technology market share for all electricity markets in ecoinvent 3.3. Both a business as usual (BAU) scenario and an aggressive climate scenario (450 ppm) were examined for the year 2050. The two updated versions of the ecoinvent database were used to perform prospective LCA on a future electric car charged with Western European electricity (Bauer et al. 2015 Hirschberg et al. 2016) as a case study to examine the impacts of the changes on the background database relative to the original version of ecoinvent 3.3. The authors showed that in addition to direct electricity consumption, the upstream impacts of electric vehicle production are strongly dependant on future electricity scenarios and that these differences are significant when considering the life cycle impacts of electric vehicles per kilometre travelled.

Thomas Bütler (Empa, Switzerland) noted that due to current affairs around the NOx emissions of diesel vehicles, diesel engines have become discredited. It is therefore expected that the diesel market in Europe and Switzerland will shrink. Beginning of September 2017, new exhaust emissions regulations come into force (Worldwide Harmonized Light-Duty Vehicles Test Procedure WLTP, Real Driving emissions RDE) which will lead to more realistic emission values. Besides the new emission measurement procedures, the determination of real-world energy demands remains an open issue. The difference between the standard and real-world consumption of passenger cars increased constantly over the past few years (ICCT 2016). The new procedures will result in more realistic values on average, but for specific scenarios (use of auxiliary systems), these values remain inaccurate. Empa therefore develops a tool to assess the real-world energy demand of vehicles based on the Willans approach (Bach and Soltic 2011), which is an affine correlation of energy demand and energy supply over a wide range of driving patterns. Within this approach, the partial results of the WLTP are used to create an efficiency model of the vehicle, which makes it possible to calculate realistic energy demand values for various applications and propulsion concepts. He finally points out that using real-world energy demand scenarios has a crucial impact on the outcome of an LCA.

4 Challenges in mobility related environmental impact assessment

Patricia van Loon (RISE Viktoria, Sweden) showed an overview of the current knowledge and knowledge gaps in determining the environmental impact of electric vehicles. Based on an extensive review of previous LCA studies, she pointed out inconsistencies between the different studies and a need for clear guidelines to support researchers. Important input factors like the assumed average lifespan of the car, the energy consumption during the use phase, and end-of-life impacts vary considerably, even if the same type of car is modelled. Further, emissions associated with the production and recycling of the traction battery, the charging infrastructure and the environmental impact of different charging strategies are currently unclear due to a lack of data. Collaborative research between academics and manufactures to fill the data gaps with modern electric vehicle data is advised together with a procedure on how to select relevant and reliable data.

Samuel Schiess (ETH Zürich, Switzerland) presented that noise emissions are yet often neglected in LCA, although the negative impacts on the human health are medically proven. The noise footprint model is an approach to include noise emissions in future LCAs. It consists of a characterisation with time, context and frequency specific characterisation factors that transform the mobility demand into a sound pressure level. The specified factors are also available for a conversion into the endpoint unit DALY. Before the characterisation, an adaption for different vehicle types is applied to account for the vehicle specific noise emissions.

They used the noise footprint model to calculate a Swiss noise footprint induced by the land-based private mobility needs. As input, they took the results of the large-scale traffic simulation MATSim from the Institute of Traffic Planning at the ETH.

The results show, that the total noise footprints are highest in the densely populated areas, while the noise footprints per capita are higher in rural areas. The total noise footprint of Switzerland is 9295 DALYs, while the individual road based noise emissions form the largest contributor to the results. The Swiss noise footprint per capita is a little smaller than the WHO estimates for Europe.

Thomas Peter (ETH Zürich, Switzerland) presented the latest findings related to the climate change impact of airplane emissions. He explained the main mechanisms of water vapour, of linear contrails and, in particular, of induced cirrus. The effects of induced cirrus contribute most to climate change of non CO_2 emissions. However, their effects show a higher uncertainty compared to the other effects. He showed the pros and cons of different climate metrics such as radiative forcing (RF), global warming potential (GWP) and global temperature change potential (GTP). Finally, he argued that scientists should curtail their air travels despite the microscopic dent this would cause, because the influence on society goes beyond mere numbers.

Jing Wang (ETH Zürich/EMPA, Switzerland) talked about quantifying PM emissions and health impacts. Environmentally responsible aviation growth not only necessitates an understanding of the health and environmental impacts from aircraft emissions, but also a detailed quantification of emissions. There is a lack of accurate particle mass and number emission data in particular for modern currently-in-service engine technologies. Currently used particle mass data are based on outdated smoke number certifications and large uncertainties remain in the emission inventories. Aviation emission regulations with the inclusion of non-volatile particle mass and number limits were proposed in 2016 by the Committee on Aviation Environmental Protection and adopted by the International Civil Aviation Organization (ICAO) in March 2017. Emission measurements according to the new regulation provide opportunities to develop more reliable aviation emission inventories. Mass- and number-based particle emission indices depend on engine type and conditions and are sensitive to fuel composition (Brem et al. 2015 Durdina et al. 2017). International Agency for Research on Cancer classified diesel engine exhaust as carcinogenic to humans (IARC 2012). In contrast, the aircraft emissions have been shown related to respiratory symptom for airport workers and nearby residents in limited studies (Touri et al. 2013); however, no cause-effect relationship is demonstrated.

5 LCA applications in practice

Salome Schori (SBB, Switzerland) presented three new tools for mobility-related decision making that were developed within the mobitool project. Mobitool is the Swiss platform for mobility management and environmental data for mobility. The basis of the tools are the updated mobility inventory data, the "mother of tools" is available for download as a excel version as well. The "mobicheck" tool, provides a quick mobility assessment for a business with only a few clicks. The second tool is a comparison calculator where the environmental impact of two transport options can be compared directly and relevant factors such as the fuel consumption or the load factor can be adjusted individually. The third tool "mobiplan" is an extensive tool for mobility management in companies that also provides extensive suggestions for possible measures to reduce mobility-related impacts. All tools are accessible via the website www.mobitool.ch.

Stephane Morel (Renault, France) presented the LCA activities at Renault from its beginning 20 years ago until today. Since the publication of the first LCA of a car the approach was further developed to a co-operative LCA. In a first step the innovation peculiarity and LCA issues are detected. Secondly, the relevant and appropriate stakeholders are identified and engaged for a collaborative LCA action. Thirdly, the LCA issues are elucidated with specific tools and events. Fourthly, the outcomes and benefits for the LCA and the participants are evaluated, and fifthly, actions are extended to new LCA routines and enriched partnerships. He also expressed his expectations from the LCA community to create reliable and easy tools including monetarization for decision making, to adopt a regional focus for more accuracy and to move from "what" (dividing difficulties in solvable parts, Descartes) to "how" (collaborative action).

Aircrafts have a carbon-footprint (CF) that is higher than their CO_2-emissions. The gap between science on the one side and the missing of applicable GWP (global-warming-potential) factors on the other is a shortcoming for CF. Niels Jungbluth (ESU-services Ltd., Switzerland) presented the state-of-the-art for accounting. Approaches are ranging from RFI (radiative-forcing-index) factors of 1 to 2.7 for the direct CO_2. An RFI of 2 on total aircraft CO_2 (or 5.2 for the CO_2 in higher atmosphere) is identified as best practice because it is based on scientific publications (Jungbluth 2013). This is multiplied with the CO_2 emissions for calculating the GWP of aviation.

Yorick Ligen (EPFL, Switzerland) talked about the energy footprint of battery electric vehicles (BEV) and fuel cell electric vehicles (FCEV) charging infrastructure, introducing the concept of grid to mobility efficiency. This approach accounts for losses of both charging station's equipment (power electronics, stationary battery, hydrogen processing) and vehicle side components (battery cooling, on-board charger, driving cycle measurements). Assuming a coupling with renewable electricity sources and compiling published measurements and datasheets, the results have shown that only 66–78% (BEVs) or 57–60% (FCEVs) of the grid energy input is transferred into the vehicles. As such, to drive 100 km, a BEV requires 23–27 kWh from the grid and a FCEV 52-55kWh (Ligen et al. 2017).

Rene Itten (ZHAW, Switzerland) presented on behalf of Sarah Wettstein (ZHAW) the environmental impacts of the CO_2 methanation value chain and their implications on mobility with passenger cars. Power-to-gas methane produced from carbon dioxide and hydrogen using renewable electricity, can be stored in the already existing natural gas network and used for mobility. The prospective LCA with time horizon 2020 including different scenarios for CO_2 capture from industrial waste gases or atmosphere and hydrogen electrolysis with efficiencies from 62 to 80% as well as scenarios for various electricity sources showed that GHG emissions per kilometre are lower for power-to-gas vehicles compared to conventional vehicles, if hydrogen production is powered by renewable energy. A reduction of 68% of GHG emissions is achievable in the most optimistic scenario compared to conventional petrol vehicles.

Kirsten Biemann (ifeu, Germany) talked about a shift in the emissions from the use phase of a vehicle to the production and fuel supply due to electric vehicles entering the market and an ongoing decarbonisation of the electricity sector. She stressed the need to use (renewable) electricity directly in the transport sector due to the low (around 40%) efficiency of the power-to-liquid process. However, she also highlighted the possible impacts to resource usage if an electrification of the transport sector is assumed using scenario data.

Peter De Haan (EBP, Switzerland) noted that the recycling of battery packs is key to the LCA of electric cars. A model that forecasts the new car market on a yearly basis is combined with a fleet composition model. This yields future market penetration, and the number of battery packs from end-of-life hybrid and battery electric cars. Large-scale recycling plants will be common from 2030 on. LCA of electric cars is also dominated by the power mix, preferably in high temporal resolution. As an alternative, the consequential effect of electric cars on the residual load in the distribution power grid could serve as indicator in future LCA.

6 Mobility scenarios and environmental impacts

Andreas Schafer (University College London, UK) talked about the environmental impacts of air transportation. He compared the energy intensity of different means of transportation in dependence of the scale of the transport means showing a difference of up to three orders of magnitude and aircrafts showing the lowest energy efficiency. He also showed the rather linear relation between gross domestic product (GDP) and the passenger kilometres travelled as well as the shift towards faster modes of transport. All demand projections of airplane companies and ICAO show exponential growth of air transportation reaching about 13,000 billion revenue passenger kilometres and about 500 billion freight ton kilometres by 2030. The CO_2 mitigation options in air transportation comprise air traffic management (ATM), intermediate and, primarily, next generation aircrafts, airline operational strategies as well as fuels based on renewable resources. He also emphasised the expected rebound effect due to improved fuel economy leading to lower fares and thus higher travel demands. He currently works on understanding the environmental impacts of (hybrid) electric aircrafts and the effects on the greenhouse gas emissions of air transportation.

Pierpaolo Cazzola (International Energy Agency, IEA, France) talked about the decarbonisation of transportation and its challenges. He mentioned three main elements, namely (1) changing the nature and the structure of transport demand, (2) major improvements in efficiency and (3) rapid transitions in the energy mix used to move people and goods. Ambitious policy actions are needed across all transport modes with trucks and light-duty vehicles required to contribute the largest shares to reducing the greenhouse gas emissions by about 80% as compared to 2015 (90% in OECD countries; 66% in non OECD countries). However, trucks are currently the fastest growing mode of transport (and oil consumer), and its greenhouse gas emissions will surpass those of the power and industry sectors in the near future. He showed that the activity development in air transportation outweighs the expected efficiency gains. A similar development is expected in international shipping with a doubling in the greenhouse gas emissions until 2060 in the reference technology scenario. Finally he shows that fuel decarbonisation is expected to save globally about net 100 trillion US-$, mostly from reduced expenditures on road vehicles, roads and fuel.

Sebastian Hörl and Andreas Frömelt (ETH Zürich, Switzerland) presented future scenarios of land-based mobility including autonomous vehicles. MATSim (Multi-Agent Transport Simulation) is a powerful agent-based transport simulation framework that is suitable to assess possible impacts of changes in the traffic system and people's behaviour towards new technologies (Horni et al. 2016). As a first attempt to study the environmental consequences of the introduction of autonomous vehicles (AV) based on MATSim-results, a LCA-coupled MATSim-model was set up for the city of Sioux Falls (US). In the scope of this case study, different model parameters were investigated such as the number of AV operators, operation mode (taxis versus shared taxis), prices as well as AV fleet composition. Preliminary results show that the AV fleet composition, the electricity mix (in the case of electric vehicles) as well as the substitution of conventional car trips by AVs are the most important factors affecting the environmental performance of the investigated scenarios. In follow-up research, the coupling of MATSim with LCA will be fine-tuned and the environmental implications of the introduction of AVs will be analysed in detail.

7 Plenary discussion and conclusions

The presentations and discussions showed that the demand for transportation services will likely continue to grow substantially in the next decades. At the same time, the Paris Agreement requires a substantial reduction in greenhouse gas emissions to comply with the below 2 °C scenario or even the 1.5 °C scenario. In the past years, a lot of progress was made on the models on transportation and mobility, and the knowledge on the environmental impacts of the various transport modes substantially improved. However, the silver bullet for environmentally benign mobility seems not within reach in the coming years, and reducing the environmental impacts of mobility remains a technological and societal challenge.

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