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The DLR Transport and the Environment Project– Building competency for a sustainable mobility future

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Abstract:
This article describes the thematic and organizational approach of the DLR Transport Program's research project "Transport and the Environment" (Verkehrsentwicklung und Umwelt, VEU). It illuminates the research approach, which employs scenario techniques to achieve a common understanding and a framework for the project. Establishing a platform for scientific exchange, VEU clearly facilitates the interdisciplinary integration of research on mobility within the DLR and its partner institutes. A set of transport scenarios for Germany and Europe (time horizon 2040), which are presented in greater detail in this article, is used in this respect and aims to provide answers for pressing societal questions.

1. Introduction

Ensuring mobility while also protecting people, resources and the environment is one of the greatest challenges facing us. The DLR Transport Program's research project "Transport and the Environment" (Verkehrsentwicklung und Umwelt, VEU) has been created to investigate the transport and environmental functional chain[1]. The project integrates fundamental research on new and innovative mobility technologies and concepts with socio-economic analyses of behavior, acceptance and use of these options. It continues its analysis by developing models for future mobility trends and their impacts on people and the environment. The overarching goal of the VEU project is to analyze the effects of possible future transport systems[2] with a focus on mobility developments, noise, air quality, weather patterns and the global climate. Explorative scenarios for the year 2040 are developed and quantified using the VEU model landscape. For this purpose, social developments, political measures and technical innovations are identified that act as catalysts for substantial changes in society and its transport system. The VEU-scenarios generate a joint framework guiding the institutional research and have profited from the interdisciplinary character of the project.

2. Project structure

In the VEU project basic research on specific topics is combined with applied and joint research (Figure 1), developing a set of interconnected models. The VEU project involves ten DLR institutes and two Helmholtz Centers (KIT and HZG) in a unique research network. The VEU project creates platforms for scientific exchange and interdisciplinary research on mobility. It follows the interdisciplinary approach by incorporating social sciences, mathematics, engineering, physics and atmospheric chemistry. Furthermore, it integrates medical research related to traffic noise as well as specific economic analyses. Empirical socio-economic research is linked with several models on different spatial scales. As well as focusing on passenger and freight transport demand in Germany in great detail, and for Europe in lesser detail, the project also covers global air transport. Furthermore, the results of the VEU project are embedded in global climate modeling. The interconnected VEU-models provide a comprehensive and reactive instrument for transport analysis. The instruments to create the joint research platform within VEU are: regular interdisciplinary exchanges, identifying common understanding across disciplines and developing VEU scenarios for possible futures in mobility.

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[1] The institutional funding of the VEU project stems from the German Federal Ministry for Economic Affairs and Energy.

[2] Within the context of VEU, transport systems are spatially defined as all means of transportation, including non-motorized modes, geographically focused on Germany.

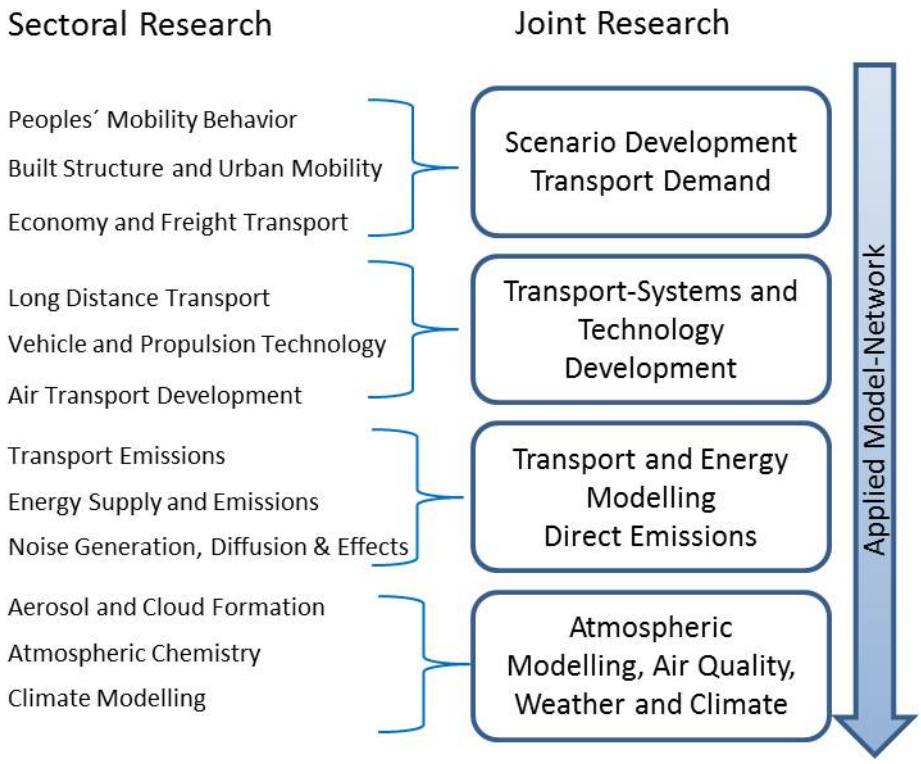

Figure 1:Relationship between basic research and joint research topics in VEU

3. Thematic elements of the Transport and the Environment project

3.1. Mobility behavior, transport generation and the modeling of future mobility systems

Transport demand reduction and the shift to healthier and less fuel-consuming modes of transportation are ways to reduce traffic's' environmental impact. Re-urbanization and demographic change are a few of the trends in Germany demanding new concepts to ensure mobility and equal societal participation. The densification in metropolitan regions opens new mobility options (e.g. cost-efficient public transport), but also poses continuing challenges including air quality and human health issues.

The socio-economic dynamics of societies, people's behavior and the role these play in for the mobility of the future are being comprehensively investigated in the VEU project. For example, issues of modal choice and traffic generation and the interrelationships between mobility and the built environment are likewise at the center of the empirical research. Furthermore, a particular focus lies on long-distance travel by road, rail and air.

The DLR transport research institutes (Institute of Air Transport and Airport Research, Institute of Transportation Systems, Institute of Transport Research) analyze official statistics (e.g. the National Travel Survey "Mobility in Germany", MID) and conduct their own empirical studies on behavior and demand. In addition, the acceptance of new concepts and technologies is also examined, of car sharing, for instance, or the use of information and communication technology, e.g., for management of logistics processes or passenger information on public transport.

The outcomes of the empirical research are integrated into transport demand models, which are developed in the VEU project. The models include discrete-choice and multi-agent approaches that can describe and forecast multifaceted transport processes. Depending on the spatial scale, specific models are deployed. The areas looked at are equally diverse, ranging from the mapping of national transport and energy systems, to small-scale, specific modeling of urban and rural areas. Results of the transport demand models feed into emission models and the chain of modeling for regional air quality and global climate effects.

The economic effects of transport on employment and the certain economic sectors have already been studied in the project's predecessors. This is now being expanded by analyzing the labor market effects of new and innovative technologies.

3.2. Technologies and energy systems of mobility

Technological improvements to existing transport technologies and the development of new ones are key aspects in achieving a more environmentally sound transport system. In the areas of rail and road vehicles, there are several possibilities to reduce consumption and conserve resources through technological innovation such as new (and lighter) materials and downsizing, alternative powertrain concepts such as fuel cells and electric motors, and new fuels, such as liquefied natural gas or hydrogen from renewable wind power. New technologies such as lightweight construction or new propulsion and fuel systems can also contribute to greater sustainability in aircraft and their engines.

Several institutes within the VEU project (DLR Institutes of Propulsion Technologies, of Vehicle Concepts and of Engineering Thermodynamics) are examining potential alternative technologies and energy systems. The markets for innovative vehicle technologies are systematically scanned, analyzed and evaluated. Production cost models are developed for essential vehicle components (e.g. for battery, fuel cell etc.) in order to assess the total cost of ownership of different powertrain concepts. Furthermore, life-cycle approaches are used to study the well-to-wheel as well as the production emissions of different propulsion concepts. The agent-based market model developed in the project can then estimate what proportion of vehicles with alternative drive trains is realistic in future vehicle fleets. Other models assess consumption and emission patterns of the commercial civil aviation.

Furthermore, the positive impact of innovative transport systems depends on the way energy is generated – for instance, whether power for electric mobility is conventionally produced or by climate-friendly means. The incorporation of models for future energy systems is thus an integral component of VEU scenario analysis and its well-to-wheel assessment.

3.3. Transport noise and its effects

Noise may harm people both physiologically and psychologically. In regions with high transport activities, noise poses an important environmental factor and many people in those areas feel disturbed by transport noise. Better understanding of where noise is created at vehicles, how it diffuses in space and how it affects people is one major task of the basic research within the VEU project.

A cluster of three DLR institutes (DLR Institutes of Aerodynamics and Flow Technology, of Aerospace Medicine and of Atmospheric Physics) analyze transport noise with a flexible forecasting procedure. In the VEU project, noise is measured across its whole range, from its generation and transmission to sound propagation and characteristics. Microphone array

technique is used in this, combined with video recording when measuring with directional microphones. This allows the causes of noise to be better understood, e.g. what proportion of car noise comes from the engine, tires or road surface, or what role braking, tracks and curves play in train noise.

The research findings are combined in models with further VEU transport development data. This enables precise assessments of future noise pollution. The noise research also incorporates factors such as demographic change, regional classifications and urban structural characteristics.

The effects of noise on people, especially on sleep, are also empirically studied. While air and rail transport has been studied, the gaps in data on road transport are being filled with new field studies. In addition, potential noise-reduction measures are tested, both technical, e.g., silent brakes, new tires and asphalt surfaces etc., and behavioral, e.g., speed limits, economic instruments etc.

3.4. Effects of transport developments on environment and society

Transport is responsible for around 24% of greenhouse gas emissions in Europe[3]. Alongside climate-damaging CO_2, transport also releases many other substances which impact local air quality. Already today, thresholds for particulate matter and nitrogen oxides are over-exceeded near many European city streets. Transport emissions such as nitrogen oxides, carbon monoxide and hydrocarbons lead to an increase in ground-level ozone, which is harmful to the environment and to human health. Besides the climate effect of transport CO_2, air emissions from transport also affect our weather and climate indirectly: soot and fine dust, for example, but also gases such as sulfur dioxide, nitrogen oxides and hydrocarbons can form atmospheric aerosol. These aerosol particles reflect and absorb solar radiation, and affect cloud formation (including contrails and contrail cirrus) and eventually weather and climate. Thus, it is crucial to study the emission effects due to changes in mobility patterns and the introduction of new concepts and technologies in order to provide society with solid knowledge for decision making.

The DLR Institute of Atmospheric Physics together with the Karlsruhe Institute of Technology, Institute of for Meteorology and Climate Research and the Institute for Coastal Research at the Helmholtz-Center Geesthacht examine the complex interrelationships between transport and its environmental effects. In the VEU project, passenger and freight transport emissions, embedded in the emissions from other European and global sources, are quantified by using an emission inventory model for Europe and continuously improving it with original data. For example, transport demand results are integrated for more precise effects modeling. The impact of pollutants on air quality, climate and weather are subsequently analyzed with the aid of simulations via numerical models, supplemented by airborne atmospheric measurements. The emissions' effects are both analyzed for the actual current status and forecast for potential future developments. The particular question here is how future mobility systems would affect the environment.

4. Solving the interdisciplinary challenge of the research project

The VEU project uses scenario approach, which firstly brings together the basic research of the individual aspects. Further, it helps the project to achieve its goal of analyzing the effects of possible future transport systems, focusing on mobility, noise, air quality, weather patterns and the global climate Within the scenarios social developments and political measures are identified

[3] Figure by the European Environmental Agency for 2012 including international maritime and aviation emissions. (EEA 2014)

that act as catalysts for substantial changes in society and its transport system. The scenarios are exploratively developed for Germany within Europe in the year 2040. The scenarios are then quantified using the VEU model landscape. In this way, the scenario research fosters the cohesion of the individual research tasks.

4.1. Creating a common understanding through transport system scenarios

The aim to work in an interdisciplinary fashion, embracing the entire cause-and-effect chain from microscopic transport demand to global climate modeling is ambitious. Network meetings and a woven fabric of thematic clusters have been used in order to find a common language and to be able to process data throughout the various disciplines. Furthermore, all institutes have been engaged in creating the VEU scenarios, following principle recommendations by the German Environmental Agency (UBA 2011b). The multidisciplinarity of the project participants enabled the VEU scenarios to be created in-house by incorporating experts from engineering, mathematics, physics, planning, social sciences and many more. This approach ensures the recognition of topical research from the various disciplines.

The project has used impact-uncertainty and cross-impact-analysis in developing consistent explorative VEU scenarios. The cross-impact-analysis belongs to the “probabilistic modified trends” scenario methodologies and combines quantitative and qualitative factors for scenario development. Qualitative factors are particularly appropriate for projects with a large scope and long time horizon such as VEU (Amer et al. 2012). We first collected relevant scenario parameters with a collective brainstorming in the STEEP categories (Society, Technology & Energy, Environment, Economy and Politics). Using an impact-uncertainty-analysis, the most critical and suitable parameters for scenario developments were identified. Parameters with a high impact and high uncertainty are those of particular interest (or critical scenario parameter, Wilson 1998) for scenario development. Additionally, some parameters of high impact and a degree of certainty (e.g. population) might be used for scenario development as well. In VEU, out of originally 240 parameters 13 have been filtered as the most relevant ones using the impact-uncertainty-analysis.

In a second step we conducted the cross-impact-analysis, using the Zirius open source software[4] by the University of Stuttgart (Weimer-Jehle 2006). Starting with the depiction of possible development paths for each scenario parameter, the cross-impact-analysis is an advancement of scenario consistency analysis. The cross-impact-analysis provides combinations that are internally consistent, meaning that their interdependencies do not contradict each other. In our case, about 900 scenario parameter combinations were theoretically possible. Applying the Zirius cross-impact-analysis resulted in nine fully consistent scenario parameter combinations. Figure 2 illustrates the VEU scenario process.

[4] http://www.cross-impact.de/deutsch/CIB_d_WWJ.htm, http://www.zirius.eu/index.htm

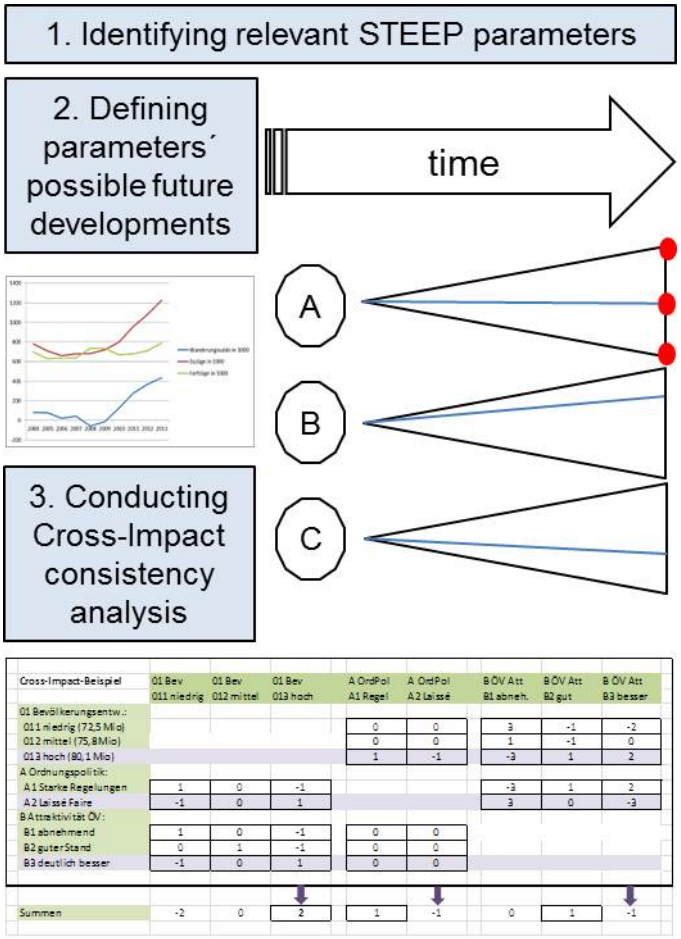

Figure 2:The VEU scenario process

Of the nine fully consistent combinations, the project team chose three to be developed as VEU-scenarios. Besides a reference scenario in which already observable developments and trends are continued into the future, two differing scenarios were created based on specific societal paradigms. One VEU environmental commitment scenario envisions a transport system in 2040 in a society that is thoroughly geared towards environmental protection. Measures aim to reduce the discharge of air emissions, climate-relevant gases and noise. Resource- and energy-efficient production and consumption are core elements of politics and social contracts. A contrasting VEU scenario pictures a transport system in 2040 that is a result of a society under pressure, lacking clear impulses with regard to environmental efficiency and protection. Society's priorities are assumed to foster existing structures and support domestic industry with its focus on the automotive sector and a centralized energy system.

The resulting pictures of the transport system in 2040 are subsequently complemented with concrete measures and trends as well as consistent framework conditions. The VEU scenarios are then analyzed using the VEU model landscape.

4.2. Developing a research and modeling network

Figure 3 maps the research areas and models used in the VEU project and how they are connected. The areas and models can be graded spatially (urban/local; national/European; global). They may also be grouped thematically (infrastructure/technology/economy; transport demand; emissions/weather/climate). The mapping of these areas and models allowed us to determine the communication path between them. Results from microscopic demand modeling, for example, inform the national demand modeling. Air and ground transportation join together in the long-distance transport model. Fleet and technology models are linked with the energy model and further contribute to the emission inventory model, which can analyze both local and European level emissions. Findings are processed with the atmospheric and climate models that integrate the influx of atmospheric and emissions data from outside Europe with those generated internally for the German and European transport sector.

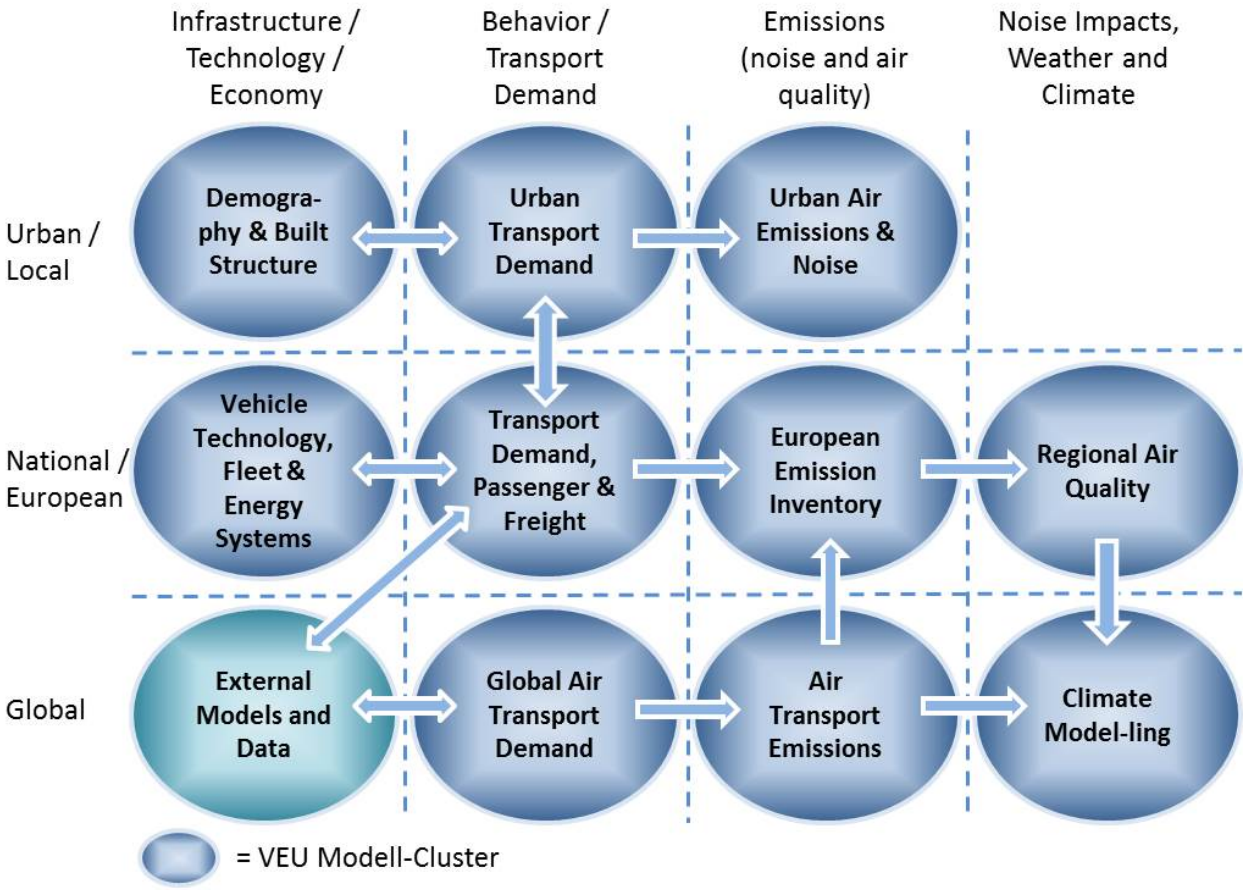

Figure 3:The VEU landscape of models

5. Conclusion

The VEU project follows an interdisciplinary scientific approach. Within the VEU project, empirical analyses inform multiple models that are linked together in the VEU model landscape. Possible future developments are analyzed using a set of explorative transport scenarios for Germany and Europe in 2040. The VEU approach acknowledges the interdisciplinary nature of mobility and its environmental effects, providing a comprehensive and reactive instrument for transport analysis.

The VEU research network combines institutional basic research under a joint thematic approach, analyzing the entire chain from transport generation to global climate effects. The thematic approach is presented in four topical areas: mobility behavior and demand modeling; technologies and energy developments; noise generation and effects; and the modeling of air quality, weather and the climate impacts of transport. New findings are constantly recognized to better analyze transport and its environmental effects.

The identification of the research areas and models together with linking them to a comprehensive modeling instrument are major milestones achieved so far. Furthermore, the VEU scenario storylines have been established, setting the principle development path for 2040. In the coming months scenarios will be further defined by concrete measures and the models and their interfaces will be tested. We expect modeling results for the scenarios starting in mid-2017.

With our research and our results we aim to strengthen the incorporation of transport in integrated environmental assessments and to open up new insights regarding possible future transport

developments. Our results aim to inform supra-national, national and local decision makers so they can better evaluate policy decisions guiding transport developments. The project website may be accessed for further information at www.dlr.de/veu .

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