NETHERLANDS ENVIRONMENTAL ASSESSMENT AGENCY (PBL) AND
INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS (IIASA) WORKSHOP ON

ENHANCING THE STATE OF TRANSPORT MODELING IN IAMS

AN EXPERT MEETING CARRIED OUT WITHIN THE FRAMEWORK OF THE EUROPEAN COMMISSION FP7 ADVANCE PROJECT

Background of the meeting

Research within the FP7 ADVANCE project strongly focuses on enhancing the representation of energy demand in integrated assessment models (IAMs), both by improving the description of energy services and end uses (WP2) and by better capturing spatial, social, and policy heterogeneities, including consumer behavior and preferences (WP3). Transport is a particularly important demand sector within these models, given that energy use and carbon emissions are increasing quickly and the mitigation of these emissions can be difficult to achieve. The purpose of this joint PBL-IIASA workshop was to bring together transport experts from various areas in order to share their extensive knowledge on the sector and ultimately to provide guidance for how to enhance the state of transport modeling in IAMs. Topics covered during the day-long meeting included data, behavior and infrastructure.

Opening remarks

Keywan Riahi, *International Institute for Applied System Analysis, Austria*

As the co-host, Riahi welcomed all workshop participants and gave a short introduction to IIASA and the town of Laxenburg. He also described how one of the first transport innovations of the modern era (train travel) contributed to the town's development.

Detlef van Vuuren, *PBL Netherlands Environmental Assessment Agency, the Netherlands*

van Vuuren, one of the workshop co-organizers, explained that IAMs tend to include more technological detail on the energy supply side than on the demand side. Many studies show that there is great potential for reducing greenhouse gas emissions from energy supply. In contrast, fewer analyses have explored the potential for energy efficiency; the ones that have (e.g., the Global Energy Assessment) indicate that efficiency can be a key mitigation option in achieving long-term low temperature goals. Therefore, for the IAM community it is a high priority to enhance the representation of energy demand in their models, and specifically within the transport sector.

Session 1: What is the current state of transport modeling in IAMs and where should it go?

To advance the state of modeling, it is important to understand the current 'lay of the land' and how the integrated assessment modeling community arrived at this point. This session provided an overview of the present state of transport modeling within IAM frameworks, as well as the challenges that lie ahead. The evolution of these models was discussed from both present-day and forward-looking perspectives.

Chair: David McCollum, International Institute for Applied System Analysis, Austria

Speakers: Bastien Girod, Tom Longden, Oreane Edelenbosch

Bastien Girod, *ETH-Zurich & PBL Netherlands Environmental Assessment Agency, Switzerland & the Netherlands*
Girod presented his comparison study of five IAM transport models. A key finding was that projected service demand growth drive total emissions in all models (annual growth of service demand is 2.1 to 2.9 % for travel, 1.8 to 2.8 % for freight, compared to 1.1% to 2.2 % for direct CO_2 emissions). The main transport modes for global GHG emission are: cars, air travel, and heavy trucks. The share of air travel in total emission is poised to increase in future, which is most pronounced in models that consider the increasing value of time costs for travel mode choices. There are other modes (e.g. rail) that would be relevant for mitigation (mode shift), but little change in mode split is observed even at high carbon prices (200 USD/tCO2). To improve the IAM transport models, the following is needed: a better understanding of potential transport development pathways in transitional and developing countries; an enhanced representation of the response to a carbon tax (with respect to service demand, mode shift, efficiency, fuel mix); and improved modeling of alternative fuels and fuel prices.

Tom Longden, *Fondazione Eni Enrico Mattei, Italy*
Longden focused on four major areas that are important for modeling transport: fuel mix and carbon reduction potentials, fuel efficiency and technical change, demand for travel and freight, and modal shifts. Scenario projections of IAMs were compared and embedded within a wider sectoral study context, based on the work that was done for the IPCC AR5 report. In terms of fuel mix and carbon reduction potentials, IAMs show results that are similar to non-IAM transport model results. Fuel efficiency and technical change are areas where details should be clarified and refinements should continue to take place. In addition, freight was highlighted as a particularly challenging sector to model in IAMs. Unresolved issues include how to represent sea and air, and should demand be linked to GDP or can industrial composition be taken into account. Finally, Longden suggested that modelers should start thinking about how IAM outputs can be maximally effective for consumers of such information. This includes making divisions in and/or reporting variables based on: public/private personal transport, road/rail freight, and sea and air.

Oreane Edelenbosch, *PBL Netherlands Environmental Assessment Agency, the Netherlands*
Edelenbosch summarized one of the first major activities within the ADVANCE project: taking stock of the current representation of energy demand models within the IAMs involved and attaining an overview of their ambitions for improving these models. Edelenbosch focused her talk on the transport sector stock-taking, of which results from eleven models were available. She noted large variations in technological detail across the models – in terms of the number of modes and technologies considered, which costs are taken into account, how efficiency is represented, and the relationship between demand and its drivers. The modeling ambitions of the teams could be categorized into four categories: improving technology representation, improving the historical and calibration data, more heterogeneity, and including infrastructure cost.

Discussion and questions from the audience
Andre Lucena (UFRJ, Brazil): The global “bottom-up” transport models are quite detailed, but are they detailed enough? City-scale models can be more useful for informing policy on the ground.

Felix Creutzig (MCC, Germany): Regarding the discussion of infrastructure (road/rail networks, etc. vs. new refueling systems), he would add a third type of infrastructure that models could/should consider: the built environment. It could be a fruitful exercise to couple global IAMs with local models for the built environment.

Robert Pietzcker (PIK, Germany):
The question is, what for do we try to improve the IAM transport models? We should only put in more details if these improvements actually influence the aggregated results, not only for detail’s sake. We also have to think about how to design new model comparison scenarios that make explicit the newly-introduced range of policies and options beyond “one carbon price”, such as policies to change infrastructure/city design, or travel behavior.

Lew Fulton (UC DAVIS, U.S.A.): Regarding the practice of applying transport metrics developed for one region to other regions, Fulton would argue that this does not work in many cases. For instance, people in developing countries probably have higher price elasticities than their counterparts in the US and EU, so we cannot simply use the numbers calculated from US/EU data.

Session 2: What transport data is available and what more do we need for IAM work?
Model results are driven in large part by input data and assumptions: this is as true for transport modeling as for any other energy sector. Various sources of transport data exist, but where are the best places to find it? Are particular data sets better than others? How certain or uncertain are the numbers thought to be? What do we do about gaping holes in the data for particular countries and transport modes? Is it possible or useful to construct an historic database for common use throughout the research community? What is the best way to harmonize data across models?
Chair: Detlef van Vuuren
Speakers: Jari Kauppila, Lew Fulton

Detlef van Vuuren, *PBL Netherlands Environmental Assessment Agency, the Netherlands*
van Vuuren stressed that an essential element of transport models is data, in terms of activity levels (e.g. pass-km by mode), energy use per service unit (e.g. energy use for cars), energy use for different technologies (e.g. gasoline vs. electric vehicles), relevant prices and taxes, and a variety of cost information. Several modeling teams are in the process of collecting their own data to support model development. Yet, these parallel activities are not the most efficient use of constrained resources across the IAM research community. Sharing data between the ADVANCE teams would not only save time, but also present the opportunity to check the data on inconsistencies. This could be done in a database, similar to the GTAP database, or alternatively in a meta database, where the available data would be summarized and direct links to the providing institution would be available. In the latter case the data would continue to reside at the organization that originally provided it.

Jari Kauppila, *International Transport Forum (OECD), France*
Kauppila described how the ITF continuously collects a large amount of transport data at the country level (e.g. ton-km, pass-km, investment in infrastructure, CO_2 emissions, road safety). This data, much of which is freely available online, is based on surveys and cooperation with other organizations. For example, the ITF/Eurostat/UNECE questionnaire contains 800 transport variables, however, this is not online yet. ITF publishes a “Glossary for Transport Statistics”, which provides a basis for international comparability in data reporting and measurement. One of the ITF’s goals is to ensure that data collected across countries is somewhat harmonized.
Kauppila then put forward the challenges in transport data collection and analysis:

- Achieving a common understanding across countries on what data should be collected and how. Comparability is affected by lack of data collection criteria and definitions.
- Good information on origin-destination pairs, non-motorized transport, and differentiation between rural, inter-urban, urban transport data is at this moment difficult to find.
- Continuity is a problem: some data collection activities are started but then later discontinued.
- Responsibility for collecting data is often fragmented, and global data initiatives are often not integrated with domestic data activities. No global mandates exist for data collection.

In terms of solutions to the above challenges, coordinated efforts are needed (e.g., SLoCaT, ITF, IEA, UN-DESA) to reduce fragmentation. Also, using data collected by public authorities for other purposes (e.g. customs data) could provide a solution to overcome the limited data availability.
Finally, Kauppila suggested that there could be ways for ITF and ADVANCE to work together in these data collection exercises.

Lew Fulton*, University of California, Davis, U.S.A.*
In Fulton’s opinion, the problem is not only that we lack data, but also that there are often multiple data sources. When different modeling groups use different sources, this results in different starting points in scenarios. It is especially difficult to collect the number of km that vehicles travel per year (especially in non-urban areas). IEA derives these numbers through using other data.
The International Energy Agency maintains the IEA Transport Database, which covers 33 single countries and 8 aggregate regions and tries to harmonize bottom-up and top-down data. Besides national statistics, which do not always contain consistent data, potential data sources are industry/consulting firms (e.g. Marklines, POLK, Walsh), the ORNL Transportation-Energy Data Book and GIZ (Germany). Alternative ways of data collection could be via vehicle registration data, vehicle OBD (on-board diagnostics) systems, household surveys, logistics and trucking company surveys or new data collection technologies. Fulton commented, however, that it is generally not the job of the transport modeling community to go out and collect this fundamental data; instead, we have

to rely on what is already out there.
With an eye toward improving data availability and accessibility, Fulton differentiated between different milestones that could be achieved by the transport research and statistics communities:

- Short term: Working together and sharing data among individual groups/teams
- Medium term: More structured sharing and working together between countries to improve their data collection systems. Notable in this respect is the Asian Development Bank's (ADB) "Global Transport Intelligence" initiative.
- Long term: Develop a common international framework/methodology for cost-effective, ongoing data collection systems that countries could adopt. Fulton noted that the United Nations' forthcoming Sustainable Development Goals might list transport as a goal, if it does, then transport data collection may form a major part of this effort.

Discussion and questions from the audience
Jari Kauppila: Often discussions on future transport systems largely focus on building new infrastructure and the transition process. But what about managing existing infrastructure better? It is surprising how little transport ministers think about this question.

Bas van Ruiven (NCAR, USA): IAMs only really need a few transport data variables for their work, so a role of ADVANCE could be to prioritize what exactly we need in terms of data. We don't need all 800 variables that ITF produces.

Bastien Girod: The integrated assessment modeling teams are mainly interested in time series data. What is your experience with these types of data?

Alexander Körner (IEA, France): A good place to look for transport data is the Global Fuel Economy Initiative. They have generated a time series of fuel economy from 2000 to 2011 for 26 countries (both OECD and non-OECD countries; major data effort especially for non-OECD countries), and it is publicly available. This would be a great place to start for IAMs for getting fuel efficiency of vehicles in our models.

Lew Fulton: There are very good opportunities for low-cost surveying exercises to collect data. An example is a 5-minute survey at fuel stations which was performed in Mexico.

Jari Kaupila: A different approach would be to look at so-called "big data", which is becoming increasingly available in different areas. However, it takes a lot of time and effort to clean this data, and complex algorithms are needed for data processing.

Session 3: Key determinants of mode choice and service demand - how can IAM transport models be improved to reflect heterogeneous behavior and consumer choices?
Capturing consumer choice and behavior in numerical models is an acknowledged challenge, especially in the transport sector, given the myriad market imperfections. This session discussed key determinants of mode choices driving transport energy demand, and how these vary within a population, over time, and spatially.
Chair: Charlie Wilson, University of East Anglia, Tyndall Centre, United Kingdom
Speakers: Jillian Anable, Mark Jaccard

Jillian Anable, *University of Aberdeen, United Kingdom*
Anable expressed concern that, with exceptions, the classical rational agent approach is still dominant in modeling transport. This is surprising, she said, given all the research that has been carried out in the behavioral economics and sociological domains. Anable listed the many determinants of travel behavior and stressed that it is impossible for a single model to include everything, simply because it would be too complicated to do so. Moreover, modeling behavioral changes is broader than just mode switching. How cars are driven and how much they are used are important aspects that are affected by behavior as well.
Recently a mostly unpredicted phenomenon known as "peak car" has been observed in the transport sector of developed countries, where especially in higher-income groups the levels of private auto transport have fallen.

Whether this is due to saturation, a real turning point in behavior, or just a temporary blip, remains an unresolved debate.
Anable ended by discussing two studies that she performed, where including behavior aspects to the scenarios created, resulted in a better understanding of the transport system and choices made.
Some conclusions and challenges for IAM transport modeling include the following:

- Doing “off-model” scenario work has a lot of value (i.e., developing scenarios outside the model and then feeding them in), as there are too many behavioral features to include in IAMs.
- Data does not readily exist on these behavioral features in different choice / national contexts.
- The best transport modelers are the ones who are interested in the entire transport sector (and all the related complexities), not just in modeling per se.
- It is important to look at non-cost factors and segmentation.
- Systems thinking is important. Many influences on transport service demands do not come from the transport sector (built environment, ICT, retail patterns).
- Including policy diversity in the scenarios is necessary.
- Be realistic about what IAMs can do: “IAMs will simply be an aid to (some) thinking – nothing more.”

David Greene (Oak Ridge National Laboratory and University of Tennessee, USA): How well do you think we can put a dollar value on the willingness-to-pay for new vehicle technologies?

Jillian Anable: For the 2% of the market who are innovators, perhaps we can do this. For the majority of the market however, it’s much harder. The late-adopter is much harder to predict. It is quite possible, for instance, that the types of people who are at present very averse to adopting new technologies (e.g., EVs) might be the same group that very quickly switches to wanting them in the future. In this and other cases, it’s about more than just costs, at least much more than the manner that models tend to treat behavior and choices.

Mark Jaccard, *Simon Fraser University, Canada*
Jaccard described a set of approaches for modeling transport behavior. He and his team have worked for many years on the hybrid energy-economy model, CIMS. The transport part of this model includes three key behavioral parameters:

- Discount rate (r)
  - Jaccard’s goal is to unpack the discount rate and explicitly model certain behavioral aspects.
  - This requires empirical research to separate these out.
- Intangible costs (i)
  - Technology-specific decision factors, especially differences in quality of services and risks
- Market heterogeneity (v)

The parameters for these behavioral aspects are estimated based on discrete choice surveys for modal choice, with both stated and revealed preferences. In addition discrete choice surveys for commuter modal choice have been performed. The hybrid model is used to estimate key parameters in aggregate models by (1) introducing a price-shock in the model in order to test the response surface, (2) taking this pseudo data for estimating parameters of production function (CES, Translog), (3) generating energy-capital inter-fuel elasticities of substitution, and (4) feeding these elasticities into a CGE model.

Discussion and questions from the audience
Keywan Riahi: What do you think about using intangible costs calculated for one region and applying those to another region? During the GEA we had difficulties with this for energy access.

Mark Jaccard: This can indeed be a challenge. There is no perfect way to do it.

Jillian Anable: Perhaps this can be done in certain instances. After all, behavioral assumptions in models should not necessarily be held to a higher standard than all the other technological assumptions that are in the models. Modelers routinely use technological parameters developed for one regional context and apply them to another.

Detlef van Vuuren: In ADVANCE WP2 and WP3 our plan is to do something similar as Jaccard and colleagues have done with CIMS and their CGE. Using certain more detailed IAMs to run a variety of price-shock scenarios and then taking the elasticity results and applying those to other models. van Vuuren proposed that to Jaccard and his team to be involved in this effort.

Mark Jaccard: A question to Jillian Anable: When creating behavioral scenarios, how do you take into account feedback effects such as much less driving, thus less road congestion? Doesn't this argue for endogenizing certain relationships in models?

> **Jillian Anable**: It depends on the scenario design and the question of interest.

Bas van Ruijven: What is your experience with how much consumers differ across countries? At the end of the day, we are all human; we are not completely irrational.

> **Mark Jaccard**: Many things have to be done exogenously – he agrees with Anable on this point.
> **Jillian Anable**: There are so many types of variability. We are just now at the point of accepting the fact that there is a large amount of variability in any one single population. We need to better understand (1) how behavior changes amongst small groups of people (cross-sectional studies), and (2) how behavior of individuals changes over time (longitudinal studies).

Volker Krey (IIASA, Austria): It would be nice to come to a place where we can divide up behavioral issues into (i) things that *can* be influenced by policies, and (ii) things that *cannot*. This could help us to prioritize what types of things we try to endogenize in our models.

> **Jillian Anable**: Models are very important in policy making, whether one likes it or not. Because costs are at the core of all models, we end up with policies that are largely economic and based on fiscal instruments. The first step is getting people/policymakers to start thinking in a different mindset. There is plenty of evidence to suggest that there are many other non-cost factors at play.

Jillian Anable: Important final point: Don't forget non-modelers in modeling work. Don't just treat non-modelers as an add-on to your work. There's a lot that we can learn from the work they are doing (e.g., social science).

Session 4: How can transport infrastructure be better modeled in IAMs?
The complex networks supporting person and freight mobility are fundamental elements of the transport sector, even if they are not fully represented in many IAMs. This session reflected on which of these elements are most critical to model and how best to model them. For advanced vehicles and fuels this potentially includes representing pipelines, refueling stations, and fast-chargers, among others.
Chair: Robert Pietzcker, Potsdam Institute for Climate Impact Research, Germany
Speakers: David Greene, Hannah Daly, Alexander Körner

David Greene, *Oak Ridge National Laboratory and University of Tennessee, U.S.A.*
Greene stated that many studies quantify the costs at different scales of alternative energy infrastructures. The real difficulty lies in modeling the transition towards these new infrastructures, which might require a new public policy paradigm. Greene's opinion was that it may not actually be necessary to model these transitions entirely within the frameworks of IAMs; however, it is important for IAMs to include transition costs. The question then becomes: Is the goal to model the causes or consequences of the transition? This has implications for the modeling approach: endogenously or through scenarios.
Greene's previous work for the U.S. National Research Council indicates that in the long term the benefits of sustainable transport outweigh the costs. Model runs have shown that there are tipping points for the penetration of advanced vehicles and their accompanying infrastructure. This makes initial investment subsidies an important policy tool. The overall cost of a transition to either hydrogen or electric vehicles could be fairly sizable in the near term, but is probably quite small in the long term. Because of this, it is probably enough for IAMs to account for transition costs simply through long-run average costs. More detailed scenario modeling tools can then be used to understand the transition dynamics.

Mark Jaccard: PHEVs do not see much penetration in the NRC studies, but they do very well in consumer surveys that he has performed. In these surveys, people indicate that they would be willing to pay extra for PHEVs.

> **David Greene**: This is largely a function of the PHEV assumptions used in the NRC modeling. In some sensitivity analyses they did actually see much greater penetration of PHEVs.

Volker Krey: What would be the best manner to incorporate the early-stage infrastructure costs in IAMs?

> **David Greene**: I leave it to the modelers to decide, but it makes sense to me to simply include an extra cost mark-up on vehicles in the early years of the transition. This will be relatively small compared to the overall cost of the car.

Hannah Daly, *University College London, United Kingdom*
Daly discussed how in public planning and policy, the "predict and provide" approach to infrastructure planning for roads and aviation has dominated in recent decades. Incidentally, this approach is also what is largely applied in scenario modeling. There are several approaches to model behavior, demand, and infrastructure: (1) scenario/what-if/off-model analysis, (2) logit-based approach, and (3) adding non-technology and fuel costs. The advantage of using energy systems models for climate policy analysis is that different carbon mitigation options can be ranked based on their relative attractiveness. Ideally, the modeling of transport in an energy system framework would break out systems optimization from maximization of individual utility.
Daly put forward the exploratory work on incorporating infrastructure decisions in energy systems models, which she carried out in collaboration with UC-Davis. Using the TIMES models for both Ireland and California, infrastructure investment was proxied through a travel time investment parameter (TTI). This allowed for costing out transport infrastructure. Daly proposed that such an approach could potentially be explored in ADVANCE. In addition, a next step could be to incorporate supply curves for representing car and bus lanes, railroads, and airports. Such modeling techniques allow one to rank transport infrastructure investments along with other carbon mitigation options.

Alexander Körner, *International Energy Agency , France*
Körner presented the main results of a recent IEA study on transport infrastructure. The report shows that around 2% of global GDP is spent on road and rail infrastructure. Global road additions continue to grow at a rapid pace, while rail capacity has remained stagnant or even decreased. In the IEA ETP 4DS scenario (4 °C warming in long term), paved road lane-km are likely to grow by nearly 25 million paved by 2050. This will necessitate cumulative $80 trillion by 2050. In the "avoid/shift" scenario of IEA ETP 2012, there are major savings in less road infrastructure (~$20 trillion cumulative). The 2DS scenario could save as much as $90 trillion cumulative relative to 4DS spending. This is due to reduced demand and changing transport technologies.
A key question that arises in these scenarios is what is the road construction capacity limit? China has added on average 350,000 km/yr of new road infrastructure. Also, what is the density limit for roads? The IEA took the Japanese situation as an upper limit to road space per square km.
Körner mentions that the IEA has a large road/rail infrastructure database, which contains data from IRF, UIC, ITDP, and EMBARQ. In particular, the database includes cost data for more than 1300 individual projects in 110 countries.
Körner concluded by stating that in the IEA scenarios road infrastructure account for almost 20% of all cumulative transport expenditures between 2010 and 2050. Given that these infrastructure costs can be a big piece of climate change mitigation scenarios, shouldn't IAM studies include them?

Discussion and questions from the audience
Alexander Körner, responding to a question on the relation between refuelling infrastructure and behavioural aspects: Apart from biofuels (whose real potential to serve as a *sustainable* transport fuel with significant market share is still not entirely clear and which might need to play a big role in aviation and shipping), two potentially zero carbon options exist – Battery electric vehicles and FCEVs. When comparing both options we find a complex interaction of vehicle and fuel characteristics, infrastructure requirements and consumer behaviour. From my point of view high levels of CO_2 reductions can be achieved based on a pretty different vision of sustainable individual motorized transport:

- BEVs and high share of car sharing, lower vehicle ownership, long distance travel by train, overall high system efficiency – requires big behavioural change and has big impacts on other industrial sectors.
- FCEVs and vehicles with comparable service as of today, lower system efficiency due to lower efficiency of hydrogen generation and T&D, big infrastructure investments – requires much less behavioural change, has maybe less impact on other industry sectors, is less efficient with regard to PE to service conversion.

Discussion Session: Where do we go from here?
Wrap-up of the meeting.
Chair: Keywan Riahi

Keywan Riahi summarized the main topics that were discussed during the day-long workshop. Regarding data, the general impression was that there is quite a lot out there, though it is sometimes difficult to find and is a bit fragmented in nature. He reiterated Detlef van Vuuren's earlier suggestion to form a working group on data, together with the data experts from the ITF/OECD and IEA. With respect to behavior, Riahi posed the question: given the multitude of behavioral aspects to be considered, which elements do we want to model endogenously and which would be better to include exogenously? Finally, the infrastructure session revealed that there are two main issues concerning the modeling of infrastructure: how can we represent existing and future transport infrastructure (roads, rail lines, ports, etc.), particularly its cost, in models; and how do we model new refueling infrastructure for sustainable transport technologies and the associated transition phase. Riahi then opened up the floor to all workshop participants and asked what they thought are the key areas for improvement in IAMs.

David Greene: It seems that there is a contradiction here between regulatory approaches to policy (e.g., fuel economy standards) and price approaches (e.g., carbon taxes; relying on elasticities). The models can be run looking at these two approaches. The price elasticity approach will probably yield smaller reductions in energy use and emissions. Greene suggested that modelers can enhance their representation of energy efficiency improvement in IAMs by relying on studies that analyze fuel economy at the vehicle level and how much it costs to achieve those improvements.

Felix Creutzig: It is important to include infrastructure investments in IAMs. Urbanization could probably also be represented in IAMs in some way, even if only simply. Published urbanization studies available for different regions may provide guidance on how to do this. The IEA's 2DS scenario could be used as an example. In Creutzig's view, if many of the effective solutions for mitigating transport emissions are local and IAMs have trouble representing these local-scale options, then this creates a problem.

Tom Longden: The difficulty with modeling regionality and local-scale results is also seen in other fields. For instance, climate models have recently been criticized for the divergent nature of results regarding local impacts. Different climate models show very different rainfall patterns, etc. IAMs are not alone in this sense.

Lew Fulton: At a simple level it should not be that hard to include road and rail infrastructure in IAMs. Then, once the infrastructure is represented (perhaps tied to the number of pass-km or tonne-km), it's a straightforward matter to add infrastructure costs to the cost equations and objective function. If this is included, modelers can run policy scenarios where, for example, they look at the effect of not building the new road/rail infrastructure. This would cause congestion to build up in certain regions, which would cause a feedback in the model.

Page Kyle (PNNL, USA): It could be a good idea to develop a harmonized data set on passenger and freight service demands dating back to for example the 1970s. Then we could do historical runs and run them up to the present to see how far the model is off. Of course, such validation exercises only make sense to do with certain models.

Keywan Riahi: Regarding the historical validation idea, some models will inevitably fail to reproduce past trends, even after the data has been calibrated. Yet, this may be okay: one could interpret how far off the models are from past trends as an indication of how much human behavior has pushed society away from the 'optimal' solution.

Cristiano Façanha (ICCT, USA): There could be a better integration between global IAMs and sector-specific national/local models. Most of the time national/local policies are based on the latter. So if you want to make IAMs maximally relevant for policy making, then they need to be able to be updated relatively quickly to incorporate the latest policies and information – information that sector-specific models typically have. This is the value of integrating the two types of models.

Tom Longden: It would be really interesting to explicitly incorporate certain transport policy targets in IAMs and then run a policy baseline, much like how the scenarios were designed in the AMPERE and LIMITS projects. This policies would include, for example, fuel economy standards around the world, high speed rail plans in China, biofuel targets in EU and US, etc..

Keywan Riahi wrapped up the final discussion session by repeating that it would be beneficial to form two working groups within ADVANCE to push the transport modeling agenda forward: one group focusing on data and another on behavior. These groups would bring together IAM modelers and experts in these two areas.