Special Issue on Infrastructures in a Changing Environment

Claus Doll

Fraunhofer-Institute for Systems and Innovation Research ISI, Karlsruhe, Germany. E-mail: claus.doll@isi.fraunhofer.de

James Chu

National Central Univ., Taiwan. E-mail: jameschu@ncu.edu.tw

Farideh Ramjerdi

Transport Economics Institute TOI, Oslo, Norway. E-mail: Farideh.Ramjerdi@toi.no

Kenneth Kuhn

RAND Corporation, Santa Monica, CA. E-mail: Kenneth_Kuhn@rand.org

DOI: 10.1061/(ASCE)IS.1943-555X.0000128

Transport infrastructures are commonly made to last for a very long time. In Europe we can still find artifacts of Roman roads, bridges, and port facilities. In some, although very few, cases these ancient constructions are still in use now. Furthermore, in many parts of the world, including the United States, we find the initial structures of the first generation of railways from the eighteenth century in use, serving local commuter traffic and freight services on the branch lines of today's networks. Going further back in time, we find that trade on the Silk Road was a significant factor in the development of the civilizations of Afghanistan, Bangladesh, China, India, Pakistan, Persia, Arabia, and countries in Europe. Though silk was certainly the major trade item from China, many other goods were traded, and various technologies, religions, and philosophies, as well as the bubonic plague (the "black death"), also traveled along the Silk Routes.

This long-term horizon needs to be taken into consideration when making investment decisions today; most constructions erected now will impact the performance of our transport system and will shape the look of our built environment for the coming 100 years or longer. In addition to construction challenges, planners and engineers now face unprecedented changes in several variables relevant to the planning, design, and construction process of long-life assets. These include climate change, globalization and related passenger and freight demand patterns, regional demographic shifts, increasing awareness of safety and security issues, rapidly changing technologies, and new financial constraints. These challenges appear specific to regions and transport modes and apply to different stages of the transport infrastructures' life cycles.

Climate change affects the durability of materials and construction works through altering temperature, precipitation, and wind profiles. While in arctic regions the thawing of permafrost makes it necessary to rebuild entire infrastructure networks or accept the cutoff of remote regions from land transport during warmer periods of the year, other regions can get by with flood protection measures or the use of new materials for paving roads. The greatest challenges may be brought about by the rise of the sea level, already triggering enormous investments in low lying and densely populated areas like the Netherlands. In the long term the changing world climate may bring about shifts of regional and global transport demand, e.g., leisure destinations shifting from warm southern regions to regions of moderate temperatures. However, the positive aspects of climate change, such as the availability of new shipping routes, need to be mentioned.

The issue of the safety and security of global transport chains has gained relevance since the September 11, 2001, and July 7, 2005, terrorist attacks and has since then remained on top of the political agendas in many countries. Future challenges include the protection of critical infrastructures and transport activities against sabotage and terrorist attacks, but also against the impact of natural hazards. Accordingly, there is a link between security issues and the consequences of climate change. Finally, crises and emergency management handling procedures, including evacuation, medical aid, food supply, and the coordination of actors and institutions in case protection has failed, need thorough consideration to maintain the reliability of transport systems under extreme conditions.

Globalization brings about a rapid growth of passenger and goods flows between continents. In periods of strong economic development this leads to considerable shortages of seaport and airport capacity in the United States, Southeast Asia, and Europe. One of the several motors of this dynamic development is the quickly growing wealth and rising population numbers of the new rising economies, including China, India, and Brazil. Within these countries urban agglomerations attract people from the countryside so quickly that in many cases proper city planning in the exploding megacities is hardly possible. On the global and local scales, demand management, service reliability, and service quality thus constitute a major task for reshaping existing and designing new transportation systems for the 21st century.

However, the past years have shown that economic trends do not always point upward. The 2008/2009 world economic crises are by no means overcome as the U.S. economy is still stagnating, the future of the Euro area is more uncertain than ever, and even Chinese growth figures appear more modest than in years past. Certainly, this has implications for the spending capacity of the public sector for large infrastructure projects. In the light of growing demand and aging transport assets, the need for more cautious and forward-looking investment plans and more sophisticated maintenance strategies arises.

Like the economy, transport demand figures are not always on the growth track. In Japan, China, many European countries, and some of the U.S. regions, the population is aging and declining owing to low birth rates and migration processes. In post-reunification Germany this process is particularly evident. Despite fast and expensive investments in new infrastructures, the population of the former socialist part of the country has strongly and rapidly declined after 1990, such that many sections of brand-new motorways, rail lines, airports, and ports are now widely underutilized but still require considerable maintenance funds. As this also holds for other areas of settlement, more flexible long-term infrastructure planning tools are required to control the cost burden for future generations.

J. Infrastruct. Syst., 2012, 18(4): 229-231

While most of the listed challenges refer to generally negative impacts, current and upcoming trends in technology bear the potential to mitigate at least some of these threats. Driver assistance systems, vehicle-to-vehicle and vehicle-to-infrastructure communication systems, satellite-based services, and video surveillance can make traffic flows safer and can help control congestion and service quality more effectively. New materials and sensor technologies in infrastructures can ease the process of maintenance planning and add to a network of intelligent infrastructures. Eventually, integrated multimodal computer-based planning and simulation techniques might enable new capacity provision and network operation expenditures to be better adapted to current and future demand patterns and thus make transport infrastructure more efficient and smart.

Many of these challenges were discussed at the 12th World Conference on Transport Research (WCTRS), which took place from July 11–15, 2010, in Lisbon, Portugal. During the conference, the Special Interest Group (SIG) 5 on transport infrastructures of the WCTR identified a series of papers addressing the issue of infrastructures in a changing environment from rather different perspectives. Issues discussed by the papers touch long-term settlement planning, the funding of megaprojects, pavement rehabilitation techniques, infrastructures for biofuels in freight transport, high-speed rail services, and evacuation procedures. The selection of papers does not cover all aspects of future challenges but presents the spectrum of what has been discussed during the WCTR conference. Thus, the present special issue is to be understood rather as a collection of sample papers that have been written independently of each other and not directly considering a common topic. However, during the revision of the papers the authors have been asked to consider future challenges and solutions in their work.

The papers selected for this issue can be grouped into three thematic areas: (1) optimized investment strategies, (2) optimized road maintenance and operation models, and (3) modernizing railway networks and services for the 21st century. The main conclusions of the contributions can be summarized as follows.

Because the investments for infrastructure are always substantial and have long-lasting consequences, three of the papers selected in the special issue study the optimization of infrastructure investment strategies from three different directions. In the featured paper of the special issue, Klug and Hayashi study the impact of urban sprawl on the local infrastructure. They carefully select six indicators of urban sprawl and two indicators of private mobility as the predictor for local infrastructure stock, which serve as the proxy for infrastructure cost and efficiency. On the basis of the data of Munich, Germany, and Nagoya, Japan, they estimate multiregression models and find that the infrastructure stock is significantly influenced by the degree of urban sprawl. The models are useful for providing valuable recommendations for regional land-use policies and improving efficiency of local infrastructure. Next, Szimba and Rothengatter observe that the projects of transport infrastructure are often planned independently using cost-benefit analysis, even though clear interdependence exists within a transport network. They formulate cost-benefit analysis considering interdependence with dynamic mixed integer programming and develop a heuristic method for solving large-scale problems. The proposed approach provides more accurate and reliable results and can be expected to improve the quality of investment decisions. Koike, Tavasszy, Sato, and Monma develop and calibrate an economic model to evaluate the spatial incidence of benefit provided by road network investments. The objective of the analysis is to determine the optimal investment shares for cross-regional road infrastructure among local governments. The results show that the spatial incidences differ greatly for development and maintenance stages and under usual and disaster cases. These incidences should be taken into account in the consideration of investment allocation.

World road networks have expanded quickly in the past decades and are most likely to continue growing in the future. This levies a considerable maintenance burden on public households or private concessionaires as soon as the networks exceed their average life span or are hit by natural catastrophes. The four papers in the second category involve the modeling and optimization of infrastructure management and operation. Each of the first two papers improves one of the most commonly used methodologies for road infrastructure management. Godinho and Dias combine cost-benefit analysis with dynamic programming to optimize the timing of road construction. In addition, they incorporate stochastic model parameters and implement Monte Carlo simulation to deal with the uncertainty in the real world. As a result, the technique of cost-benefit analysis can be extended to a wider range of applications. In another paper, Kuhn addresses the computational limitation of the Markovian decision process by adopting approximate dynamic programming. In the numerical study, he illustrates that, by incorporating multidimensional data in the optimization process, more practical maintenance rules and more accurate deterioration models and cost estimates can be obtained. Schraven, Chen, Nesterova, and Schoemaker approach the issue of network quality from the perspective of supply with alternative fuels, which is of particular relevance in post–peak oil energy scenarios. The case study corridor from the busiest European freight port of Rotterdam, Netherlands, to Constanta, Romania, demonstrates that the provision of biofuels corridors can contribute to the European Union's 20% target. But because of local refueling or cross-border effects, complementary policy measures are desirable. Finally, Chu and Yeh propose a systematic approach for designing evacuation guidance in buildings with complex geometries. The paper simultaneously considers three critical factors in emergency evacuation, i.e., visibility, shortest routes, and sign coverage. The design method is valuable for facility design and hazard mitigation in pedestrian infrastructures.

Rail transport is probably the mode of transport most sensitive to external factors, such as technology, demand structures, and budget constraints. Its rapid sprawl in industrialized countries after the invention of the steam engine was followed by a sharp decline after the market entry of automobiles and trucks. Now, partly driven by urbanization and environmental concerns, powerful systems are revitalized around the globe. Chevroulet, Giorgi, and Reynaud investigate the financial results of European high-speed projects. This constitutes a serious problem as modern rail infrastructure is extremely expensive, and often cost overruns occur owing to a lack of benchmarking data. On the basis of the study EVA-TREN funded by the European Commission, several steps for better ex ante and ex post project appraisal are proposed. Garmendia, Romero, Ureña, Coronado, and Vickerman approach the issue of integrating high-speed intercity rail services with regional services by locating high-speed stations close to urban business centers. With the examples of London and Madrid it is found that agglomeration structures and location decisions are crucial to the success of this extended use of high-speed rail services. Santos and Teixeira return to the financial aspect of railway operations by investigating the effective track length that could be maintained by a tempting machine. Although significant cost saving potentials are identified, the simulations find that minimum cost solutions are not necessarily coinciding with recommended track quality levels.

J. Infrastruct. Syst., 2012, 18(4): 229-231

These results point toward a general challenge for future railway networks: raising acceptance by high quality standards often collides with budget restraints.

We thank all the authors and reviewers who have contributed to this issue and have helped to get it finalized on a high quality standard. A special thought should be devoted to colleagues from Japan, who were invited to contribute to this issue but had to withdraw their papers after the disaster of the Fukushima tsunami in February 2011. Further, we thank the *Journal of Infrastructure Systems* team, and in particular Professor Sue McNeil, for their patience in answering numerous questions and repeatedly extending deadlines. We hope that this special issue will raise interest for the 13th WCTR conference to take place in July 2013 in Rio de Janeiro, Brazil.

J. Infrastruct. Syst., 2012, 18(4): 229-231