A Vision for Transportation Infrastructure

Supported by a grant from the Association of Equipment Manufacturers, Northwestern University's Transportation Center undertook an exploration of the factors, needs, and opportunities facing U.S. transportation infrastructure in the next 35 years. The objective of the study was not to forecast the future, but to frame the possibilities and thus to inform the public and policy makers about future needs for transportation infrastructure.

The project began with an **assessment of the condition, performance, and funding** for the various modes based on publicly available data. Condition deficiencies of various degrees exist across all of the publicly supported modes – highways, public transit, inland waterways, and, to a lesser extent, airports and airways. While a general transportation infrastructure disaster is not imminent, and the condition of some elements is stable or slowly improving, the deteriorating condition of transportation infrastructure is degrading system performance – producing long travel times, reduced reliability, higher user costs, and larger externalities. Long term degradation of transportation system condition and performance is producing a subtle but important drag on the economy, and some critical bottlenecks are causing quite specific problems. Aging infrastructure is increasingly vulnerable to unexpected disruptions from natural phenomena and component failures.

These outcomes can largely be attributed to two factors: insufficient and unsustainable funding for public investment and reinvestment in transportation, and inefficient deployment of those funds that are available.

Modes operated by the private sector, notably railroads and pipelines, are generally in better condition than the public modes. In the private sector, the links between condition, performance, revenues, and profits are explicit and more closely managed than on the public side, where it is easier to ignore or defer needs because the impact on revenues and the economy is less apparent, though not less important.

The remainder of this study identified important, changing aspects of the economy, technology and society, considering the kinds of developments and trends likely to occur in the next 35 years and then assessing their likely impacts on the demand for and supply of transportation infrastructure.

The future is framed in terms of three overlapping scenarios: *business as usual,* particularly in terms of transportation infrastructure funding and investment policies; *sustainable and resilient cities,* a result of a concerted national effort combining public policies and market forces to reinvest in cities; and *competitive success,* a market-driven path that prioritizes economic gain over long term sustainability.

The chapter on **transportation infrastructure and the economy** addresses the effects of transportation technology and costs on the location and efficacy of economic activities and the structure of cities. Changing resource costs, innovative technologies such as vehicle automation, and new delivery mechanisms such as ride sharing, may be game changers that affect future settlement patterns and determine competitive advantage. Pricing the use of transportation infrastructure may become both a source of funds for renewal and a way to allocate scarce capacity. Both theory and history suggest that efficient transportation services, *ceteris paribus,* can drive economic development and global competitiveness, delivering some measure of success under any scenario.

Technological advances and value changes are creating a revolution in the way people travel, particularly in cities. The chapter on **technologies for urban personal travel** shows that information technology and market innovations are expanding the variety of options available to travelers, and young people are increasingly benefiting from that variety. The demand for variety includes preferences for non-motorized travel and increased density and diversity of cities. Planners and policy makers have new kinds and vast quantities of information with which to guide the future of transportation infrastructure and services. That future needs to include renewal and rebuilding of infrastructure to accommodate new ways of living and innovative mobility options. To respond to market opportunities, that infrastructure must be built on not only an understanding of the variety of mobility options, but also a strategy for designing smart cities and smart transportation services, sensor- and communications-based designs that will make cities and their transportation systems a central part of the Internet of Things, functioning seamlessly together.

Rapid changes in technologies and markets are already stretching the capacity of the public sector to respond, facilitate, and finance innovations, and it will be important to grow that capacity so that public policy is not a brake on system progress. In response, private businesses, which are showing increasing interest in transportation markets and innovation, are likely to take even stronger leadership roles in mobility services. The need for transportation infrastructure will change but it will not decrease, and the challenge will be to find ways to assure that infrastructure for the future.

Information and communications technologies (ICT) have become essential for managing, operating and using mobility services in both the freight and passenger sectors. While the promise of ICT sometimes gets ahead of the reality, as in the case of the substitution of communication for travel, history suggests that barriers related to the technologies themselves, skilled personnel, and attachment to old behaviors usually erode, and the benefits of ICT catch up – sometimes very quickly, as in the case of smart mobile devices.

The future is likely to be one of ubiquitous and high capacity broadband services, augmented reality tools that will affect work, shopping, system management and information dissemination, and cloud computing that will massively increase computing capacity using only modest mobile devices. That future is one in which almost everything and everybody will be connected, introducing a broader variety of integrated, coordinated service options and delivery mechanisms for passengers and freight, and very soon, high levels of automation in the transportation system.

The transformative power of ICT may, on one hand, relieve some of the capacity constraints on fixed networks, at least for personal travel, but will also demand investments in infrastructure renewal and updating to take advantage of new technologies for sensing, assessing, communicating and managing transportation systems. The risk of inaction is losing ground in the global movement to boost transportation performance using ICT as its nerve system.

The chapter on **supply chain management and logistics** describes the role of transportation infrastructure in the success of businesses, moving resources and components to manufacturing centers, products to markets, and recoverables to recycling facilities. This role is changing rapidly as eCommerce becomes the norm for both consumers and businesses. Network bottlenecks and reduced delivery reliability can affect entire production and distribution supply chains, often manifested in higher inventory costs to compensate for an under-performing transportation system, or relocation of manufacturing and logistics hubs to places where transportation, particularly intermodal service, is more efficient.

This is an issue for intercity freight, where easily accessible locations are attracting manufacturing and distribution centers from more congested places. It is also important for urban deliveries, the “last mile” challenge that can consume a large fraction of the transportation bill. That bill affects consumers, businesses, and the economic viability of places. Future freight mobility needs will focus on performance, which depends on sufficient capacity, flexibility to address costly disruptions, as well as environmental consequences of supply chain operations. Future infrastructure needs can be met in part by making more efficient use of existing capacity through operational changes, e.g., off-hour deliveries, pricing for access, new mobility models including ride sharing concepts for freight, and applications of ICT to manage supply chain operations.

The chapter on **the evolution of omni-channel retailing** describes the rapid changes occurring in retailing – the declining reliance on traditional retail stores, the burgeoning demand for direct delivery of goods – and the ways in which the increasing diversity of delivery channels places new and greater demands on transportation infrastructure. Online shopping with direct delivery has greatly expanded the demand for last-mile shipment. Today some products are marketed through face-to-face showrooms that carry no inventory, e.g., custom clothing or high-end automobiles may be shopped locally, manufactured in distant places, and delivered directly to customers. This drives the demand for both quick long distance freight movements and last mile deliveries. Increasingly in high density locations – central cities and large college campuses – deliveries go to one of a few central facilities, where customers themselves or volunteers pick up packages for home delivery. The particular modality depends on the product, its customization level, inventory costs, the ability to deliver multidimensional information about products (e.g., virtual reality technologies), and customer preferences for price and swift delivery.

This diversity places broad demands on the freight system as well as passenger travel to retail stores, showrooms, and pickup centers. Transportation cost will continue to be important, but in some cases it will be dominated by demand for efficiency and reliability. This balance can be expected to evolve as advances accelerate in experiential technology (e.g., for viewing, trying on or trying out products) and customized manufacturing (including 3D printing). As this balance changes, pressures on transportation infrastructure are likely to be felt across all elements of the supply chain.

The chapter on the challenges of infrastructure condition attributes infrastructure deterioration to aging, exposure to environmental forces, and the stresses of utilization. The consequences include delays and reduced reliability, leading to increased user costs, and in some cases facility failures and serious safety risks.

Rational, condition-based reinvestment and rehabilitation can extend facility life and performance in a cost-effective manner. Timely condition data, informing responsive decision processes, can interrupt this cycle. Increasingly, embedded sensors and wireless communications can provide those data, with more elements of transportation infrastructure monitored and connected in the future. Facilities will generate real-time information on which both users and managers can base intelligent use and investment choices. The ultimate challenge is to secure the resources and the commitment to invest them intelligently.

Transportation infrastructure and the future of cities describes cities as the economic engines that drive U.S. and global productivity. They are complex systems of flows and networks – of people, information, energy, goods, and waste materials. For the most part these interacting elements evolve independently without much planned coordination. In most U.S. cities, dependence on the automobile and low density land use, which are synergistic, extract a significant toll on the environment and sustainability. The future could bring a departure from the business as usual path toward more sustainable cities – higher densities, reduced dependence on the private auto, and more local sourcing of energy and treatment of waste products. Automobiles are not likely to go away, but their nature is likely to change radically – electrically-powered, smaller, increasingly automated, and perhaps in the long run collectively owned. Personal mobility may change so that it serves, rather defines, a new, sustainable urban lifestyle.

Moving cities on the path to sustainability will take a new level of integration and coordination, making use of emerging smart technologies, and amplified by the evolving values of younger generations. In the long term, the path to sustainability can bring competitive economic and social advantages likely to offset the costs of transition. Renewed infrastructure of all kinds will be the backbone of that path. This can happen gradually by taking advantage of opportunities to rehabilitate and restore transportation and other infrastructure components as they reach the end of their lives.

The chapter on **paying the way for future transportation infrastructure** addresses factors contributing to the long term underfunding of transportation infrastructure, reasons for resistance to increasing funding through user fees, and threats to the sustainability of the highway network from the uncertain future of the motor fuel taxes as a funding source. More direct use of user fees is offered as a sustainable strategy for funding publicly-supported transportation infrastructure. This mirrors the success that private, revenue-driven transportation services have had in the U.S. While existing and emerging technologies are changing the demand for transportation capacity, the need for fixed infrastructure will not fade in the future, and meeting that need is an essential investment in the economic and social vitality of the nation. It will be important to make the case to assure support for such investments; smart, data-driven decision must direct the funds to best uses; and a sustainable and equitable user fee system will serve to underwrite the future of a world-class transportation infrastructure for the United States.