

strategy&

***Building
sustainable,
inclusive
transportation
systems***

&

**A framework for
the future**



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Executive summary



Transportation needs are increasing all over the world — in developed regions seeking to grow their economies while reducing carbon emissions, and in developing regions where vast numbers of people are, for the first time, accessing global markets. A call for advanced 21st-century networks of roads, airports, shipping facilities, train routes, and public transportation is resounding in cities, small communities, and rural areas alike. Investment in transportation infrastructure is surging globally, with money going into the development of new transportation systems as well as upgrades and extensions of older ones. At the same time, the transformation of the global economy through digitization is driving new patterns of transport for both goods and people.

In both urban and rural communities around the globe, the challenge of moving people and cargo efficiently, safely, and sustainably — while providing transportation for all segments of society, not just the wealthy — remains a problem begging for new solutions in our increasingly globalized, urbanized, digitized, and environmentally compromised world. Long-established theories and techniques of planners and policymakers must evolve if they are to help sort out our ever more complex transportation infrastructure. We must embrace new methods and new technologies if we are to build and operate transport systems that deliver these goals while functioning inclusively, to the benefit of all.

The problems are many. Planners and policymakers need to consider that a large number of the world's transport systems cannot meet the needs of rapidly growing populations, and many passengers face safety, security, and accessibility issues. Investors need to rethink traditional approaches to cost-benefit analysis so that investments capture as many of the different impacts of transport as possible, and do so in a way that balances rigor with innovation.

If transportation planners and policymakers can successfully address these challenges, they will make a major contribution to improving the lives of people in all types of communities — large and small, central and remote — while at the same time protecting nature and making it possible to deliver the benefits of economic growth in a sustainable, inclusive way.

Transportation's global challenges

Consider Jakarta, the capital city of Indonesia. With more than 10 million people in the city proper and a total of 30 million in the metropolitan region, Jakarta is among the largest cities in the world, and still one of the fastest-growing. As a city in rapid-growth mode, it is facing tremendous challenges in terms of transportation infrastructure and sustainability.

Jakarta's streets are perpetually clogged with private cars, taxis, motorcycles, and pedestrians. Its public transport system, dominated by minibuses and dependent on an improving guided bus network but with a limited heavy rail system, is woefully overcrowded, and poorly laid out to meet the needs of its population. The number of passenger flights at Jakarta's airport has doubled during the past 10 years, but investment has not kept pace. The resulting lack of runway capacity has been a significant constraint on Indonesia's economic growth. The Port of Jakarta, regularly prone to massive delays in transshipment, has been among the least efficient in Asia, though the situation has improved since the 2016 opening of the [New Priok Container Terminal 1](#), which has added 30 percent more capacity plus a digitized system that has cut logistics costs.

The lack of transportation infrastructure is only one of Jakarta's problems, which include unmanageable growth, persistent poor air and water quality, housing shortages, and massive flooding. But the city is by no means unique in its difficulties: Other regions around the world also face a multitude of similar transport problems — not just mega-metro areas like Beijing and Mexico City but smaller cities and rural areas too. Add the need to accommodate new technologies such as [autonomous vehicles](#) and adapt to environmental concerns centered on climate change, and it quickly becomes clear that current approaches to transportation planning are unsustainable.

Planners are certainly aware of the massive transportation challenges facing cities and regions in both developing and developed economies, and they certainly understand that several overarching [megatrends](#) — urbanization, climate change, population growth, shifts in economic

power, and technological advancements — will affect the effort to find solutions. Their goals are laudable: to facilitate the movement of people and goods efficiently, safely, inclusively, and sustainably. Indeed, economic growth and technological development are driving a new revolution in transportation. Governments and private enterprises in both developed and developing economies are investing huge sums of money to further develop their transport infrastructure in the hope of improving mobility, connectivity, sustainability, and safety, and reducing time lost to congestion. According to PwC, global transport infrastructure spending is expected to total more than US\$14 trillion during the 10 years from 2016 to 2025.

But simply building more roads, airports, and even public transportation systems can amplify rather than solve the environmental and economic problems that come with urban growth. Incremental increases in capacity drive disproportionately greater complexity, cost, and concerns about sustainability. Many cities are adding new elevated highways and railways, for example. Elevated highways have become unpopular in the U.S., and recent proposals in Malaysia have also generated huge opposition from residents along the route, who are concerned about noise, pollution, visual impact, and displaced neighborhoods.

At the same time, there are major decisions to be made around inclusiveness — how to determine the level of service provision in poorer areas and the share of the cost to be passed on to users. In the case of Malaysia, the government makes an effort to be more inclusive by allowing motorcycles — the transport choice for many poorer people — to use the highways toll-free.

A further challenge involves determining the balance between government funding and private-sector investment. The significance of these challenges is compounded by the fact that anything that does get built will determine the direction of transportation flows for decades to come, while often simply moving congestion around rather than solving it.

Overcoming these challenges will require that planners take the best of the approaches and techniques they have used in the past and then rapidly develop them to better assess the wide-ranging and interrelated impacts of infrastructure on the economy and on society. The design, appraisal, and effective operation of transportation systems also should take advantage of the quantum leaps we are seeing in technology, such as autonomous vehicles and the growing ability of big data to assess, analyze, and predict real-time traffic flows.

More diversified and widely distributed systems must be built that can supplement infrastructure to optimize transportation via the free and

Transportation systems should take advantage of the quantum leaps we are seeing in technology.

transparent movement of data, and align more closely to the needs of users; too often it is the interests of operators and systems developers that come first. To accomplish all of this, planners and operators must develop a deeper understanding of the complex trade-offs among the economic, social, environmental, and fiscal impacts involved in planning any transport infrastructure project. Then they must develop new planning tools that can make use of the very rich emerging sources of data, such as crowdsourced navigation systems and smart-city solutions. Such tools can be very important in planning infrastructure as well as in optimizing its use (see “*An integrated framework,*” next page).

An integrated framework

Planning for even the simplest form of transportation — laying out a proposed route for bicycle paths in a city neighborhood, for instance — presents challenges. Scale it up to the city or regional level, and the complexities involved increase exponentially, especially at a time when the megatrends of urbanization, social and economic upheavals, and climate change and other environmental issues bear heavily on the success of even the best-laid plans. Nowadays, no region or municipality should embark on a planning effort without a guiding principle that takes into account all these factors.

To that end, we have developed an approach that we call “total appraisal,” which can help policymakers and transportation planners understand the myriad impacts and trade-offs that come into play when planning any transport infrastructure project, and identify the options that will result in the optimal outcome: a sustainable transport system that balances the needs of all stakeholders.

Exhibit A, next page, illustrates a hypothetical use of the framework to plan for a major road project. The framework comprises three main impact zones: welfare (the types of social benefits and costs that form part of the standard appraisal tool kit), economic (the impact of the project on key economic metrics that do not generally feature explicitly in cost-benefit analyses, such as the impact of a project on GDP and jobs), and fiscal (the cost of the project and its impact on various taxes). The length of the lines indicate the size of individual impacts; green lines indicate positive impacts, while red lines are negative. To use the framework, planners must assess the actual size of each impact and interpret

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it with care. One of the key strengths of the framework is how it can evolve — through the inclusion of additional impacts, for example — to properly capture the changing nature of any project over time.

Welfare impacts. Standard approaches to appraisal focus on the benefits that are likely to arise from a project. The mainstay of such analysis tends to be the value of journey time savings — the value of the time saved by being able to get from point A to point B more quickly. Other benefits, however, are sometimes included, such as the economic value of greater certainty of travel time, and the impact on productivity.

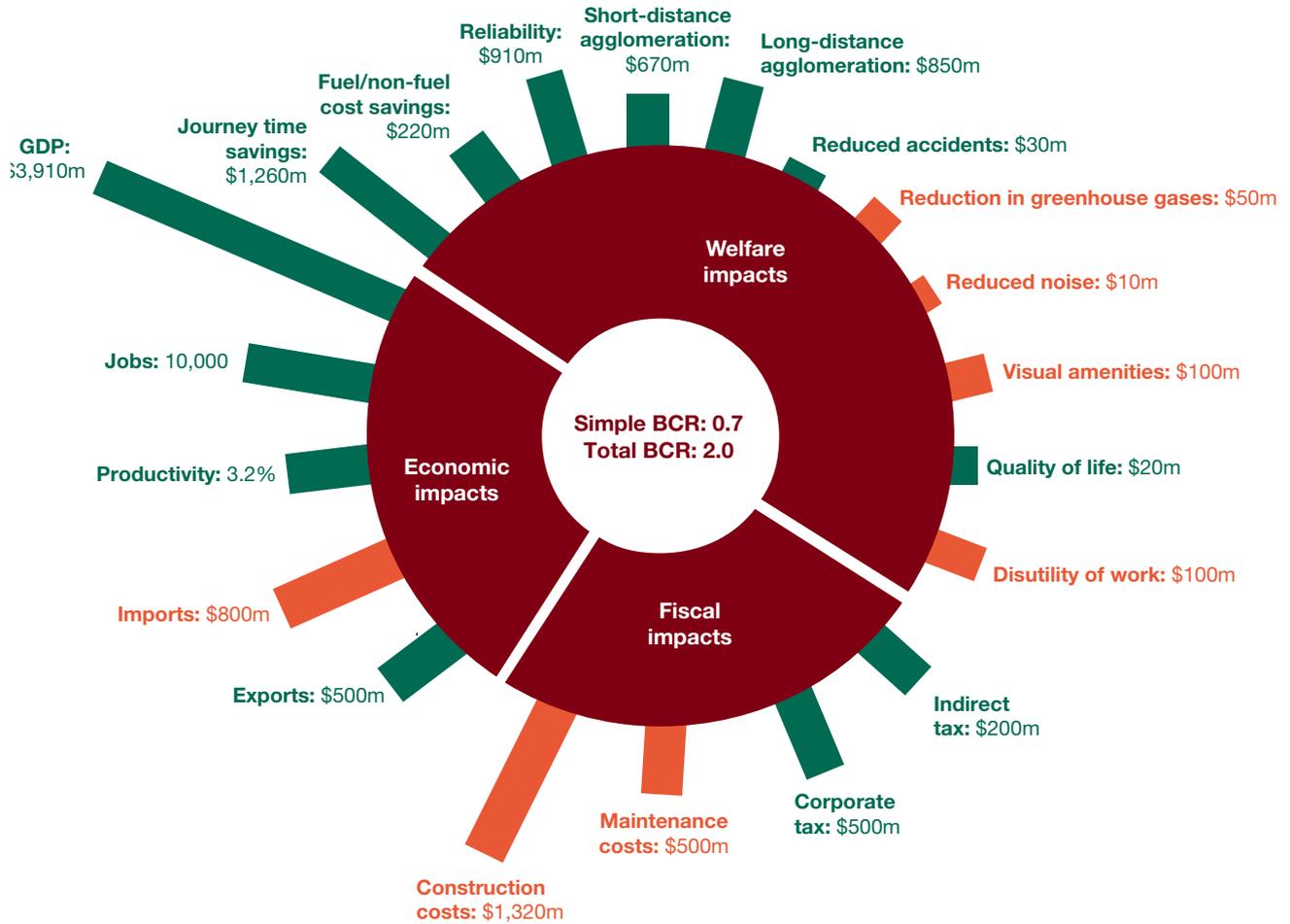
Social and environmental impacts should also be factored in, particularly if consensus can be reached on how they are measured. Key impacts include the reduction of accidents, greenhouse gases, and noise, plus the visual amenities and an enhanced quality of life if the project is truly successful.

For example, disutility of work is a crucial impact that is essential to quantify if welfare analysis is to link successfully with economic impact analysis. If a project incentivizes people to work more than before, the analysis should also factor in the value that people lose by sacrificing leisure time. It is critical to remember that GDP captures the monetized impact of more economic activity but not the value of forgone leisure time.

These benefits are then added up and compared with the costs of implementing the project, through the use of a benefit cost ratio (BCR). A BCR in excess of one — preferably substantially so, in excess of four — is required for a project to be considered

Exhibit A

Total appraisal framework for a road project — a hypothetical example (US\$)



Note: The total GDP impact is calculated as the sum of the monetized benefits arising from journey time savings, fuel/non-fuel cost savings, improvements in journey time reliability, and short- and long-distance agglomeration benefits. The total welfare impact includes the total GDP impact as well as the net monetized wider welfare impacts including reduced accidents, greenhouse gases, noise, visual amenities, quality of life, and disutility of work.

Source: Strategy&/PwC analysis

good value for the money. Different BCRs can be used, ranging from relatively simple ones such as “simple BCR,” which factors in just the value of journey time savings and impacts on air and noise pollution, through to more complex ones such as “total BCR,” which captures as many of the different impacts of a project as possible. Simple BCRs are often considered to be sufficient for small and relatively straightforward projects, whereas larger and potentially transformational projects lend themselves to the use of more complex BCRs that better capture the impacts of the project but can be controversial because of a lack of “tried and tested” methodologies.

Economic impacts. This is where the framework measures the effect of a given transportation policy or plan on a city or region’s economy. It includes the expected changes in economic output or growth and associated changes in employment, productivity, and the like.

The assessment of economic impacts is important, but it is also controversial. Although appraisals of the value of projects have traditionally been carried out based on their BCR, decision makers tend to be at least as interested in their impacts on GDP and jobs. The key is to assess the welfare impacts and economic impacts together and holistically. This is surprisingly difficult, but doing so can help policymakers make better decisions. As powerful as it is for decision makers to be able to make statements such as “The project will add \$X billion to GDP and create Y new jobs, and generate \$Z in benefits for each \$1 that is invested,” it is also crucial to be able to reconcile these figures with each other. Projects can get into difficulty when this has not been possible, largely because planners sometimes assume, wrongly, that welfare and GDP impacts are somehow the same, or can be simply added together.

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Furthermore, opinions on the benefits can differ substantially. The most contentious question tends to be whether transportation projects can pave the way for economic growth — and therefore significant numbers of new jobs — in the areas they serve. Common sense suggests that they can, but project appraisal methods often question whether there will be much new job creation in the long run. This is because they tend to assume that the impact of transport projects will be felt far into the future and that, in the long run, the economy will evolve in a way that ensures full employment. The key is to base the analysis on flexible assumptions that take into account such factors as how much spare capacity there is (and will be) in the labor market. That will enable planners to explore just how much of a difference such considerations are likely to make.

Fiscal impacts. It is crucial to understand and be able to optimize the costs of the project, as well as the extent to which these costs, and the associated financing, will be sourced from the private or the public sector. The tax impacts also need to be assessed carefully. We have found, for example, that productivity improvements resulting from people being able to travel from point A to point B more quickly — and being better connected in general — can lead to significant increases in economic activity, which in turn can lead to higher levels of tax receipts. Although these additional tax revenues are often not explicitly part of the appraisal of projects, understanding the extent to which projects can be effectively self-financing can be extremely useful in objective evaluation of the project.

Using a total BCR rather than a simple BCR to analyze the prospects of our hypothetical road allows us to capture a wider range of impacts. Put together,

they show how a project that might otherwise be viewed as marginal actually offers considerable value and should therefore proceed. Though the road will cost \$1.8 billion, it will generate an increase in GDP of \$3.9 billion, and total welfare benefits of \$3.7 billion, along with 10,000 new jobs. In addition, it will generate a total BCR of 2.0 — \$2 of welfare benefits will be

generated for every \$1 that is invested in the project for construction and maintenance. Moreover, 38 percent of the project costs could be “self-financed” through the present value of higher tax revenues.

Total appraisal is a sector-specific version of PwC’s Total Impact Management and Measurement (TIMM) methodology.

Growing demand, limited supply

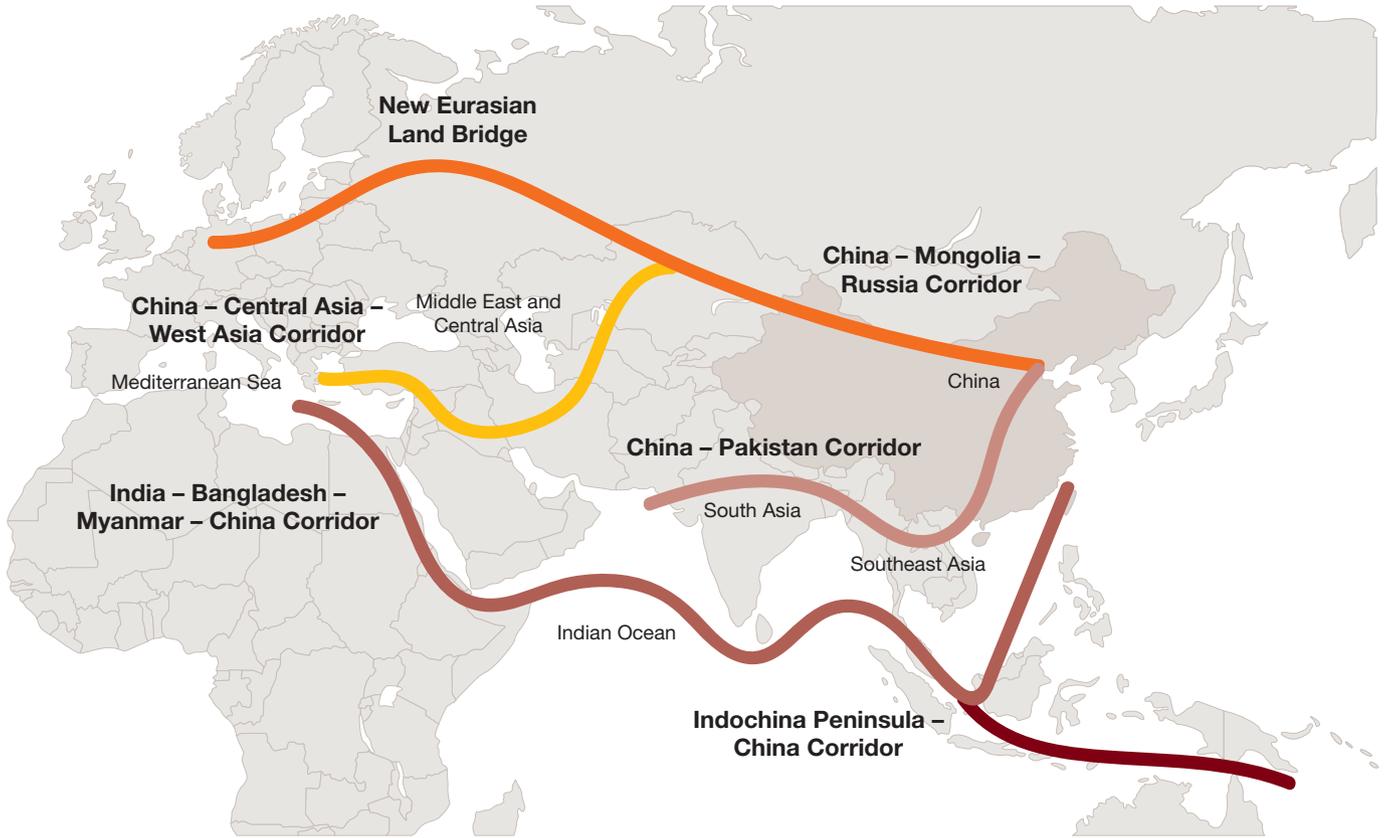
Between 1996 and 2014, container transport by rail in India alone grew 4.4 times, from 700,000 to 3.1 million 20-foot equivalent units (TEU), while road passenger transport there grew 5.4 times, from 1.4 trillion to 7.6 trillion passenger-kilometers, overtaking the United States during the global financial crisis of 2008, according to [studies by the Organisation for Economic Co-operation and Development](#) (OECD). Globally, airline passenger traffic grew 2.3 times, with low- and middle-income nations increasing 440 percent, while high-income countries saw a 79 percent increase.

China's \$1 trillion "One Belt, One Road" initiative is aimed at building transportation infrastructure throughout the old Silk Road route, across Asia and the Middle East, and into Europe and North Africa (*see Exhibit 1, next page*). In some cases, this will require building highways where only dirt roads exist now, as well as building maritime infrastructure throughout Southeast Asia and into East Africa and Europe.

Even with all of these ambitious projects under way, however, developing-economy transportation infrastructure is not keeping up with the growth in demand, particularly in secondary locations.

For example, in the quickly developing Southeast Asian archipelago covering the countries of Brunei, Indonesia, Malaysia, the Philippines, and Singapore, rapid economic growth has resulted in an explosion of logistics costs and delays, particularly outside core routes and hubs. Trucks serving Jakarta's port, which have to get there by passing through the city center, could make twice as many trips or more if they could avoid the urban congestion. The Ninoy Aquino International Airport in Manila has virtually no new landing slots, and has therefore become a major constraint on air travel growth across the entire country. And [research on shipping](#) shows that it costs more to ship a container the 1,200 kilometers (745 miles) from Singapore to Brunei in an 800-TEU vessel than to ship it the 10,500km (6,524 miles) from Singapore to Rotterdam in an 8,000-TEU vessel, due to the economies of scale of very large container ships. This is a beneficial scenario for

Exhibit 1
Land and sea routes of One Belt, One Road initiative



- █ China - Central Asia - Russia - Europe
- █ China - Central Asia - Middle East
- █ China - Southeast Asia - South Asia - Indian Ocean
- █ China - South China Sea - Indian Ocean - Europe
- █ China - South China Sea - Indian Ocean - Indonesian Coastal Ports - Timor Sea

Source: [“Vision and Actions on Jointly Building Silk Road Economic Belt and 21st-Century Maritime Silk Road”](#); PwC analysis

intercontinental shipping but not for the regional economies, which are therefore increasingly being isolated from global flows.

Growth in advanced economies is much slower — passenger miles traveled on the U.K.'s roads, for example, saw relatively little growth between 1996 and 2014 — but transportation systems in developed countries certainly continue to require significant ongoing repair, upgrade, and, in some cases, expansion, particularly as governments seek to move traffic to rail to reduce the environmental impact.

The consequences of growth

Transport investments need to be appraised in a way that takes account of the various economic, social, and environmental impacts — and reflects how cities will have to manage these issues as they continue to grow.

- **Environmental, safety, and health issues.** The world's cities are responsible for as much as 70 percent of the greenhouse gas emissions that are driving climate change — and transport is responsible for fully 14 percent of that total, 95 percent of it coming from fossil fuels. The air pollution caused by fuel emissions and other pollutants is clearly linked to negative health effects such as the increased risk of death from respiratory and cardiac conditions. In early 2013 an estimated 800 million people suffered in various degrees from particularly persistent air quality problems in China, including from motor vehicles, and the nation's government is working hard to battle the problem. Planners therefore need to consider how their systems will minimize pollution.

Meanwhile, the World Health Organization predicts that traffic accidents, which currently claim an annual 1.2 million lives globally, will become the fifth leading cause of death by 2030. In major Indian cities like Mumbai, Kolkata, and Chennai, it is estimated that road accidents cause 550 deaths each *day*. In developing countries, lack of modern, safe public transportation is driving the increased use of cars, even as most major cities are growing out, not up, making trips longer, more dangerous, and increasingly unaffordable for the average citizen.

- **Diseconomies of scale.** Transportation operators can achieve significant economies of scale by sending their passengers and freight through central hubs and maximizing the capacity of ships, aircraft, trains, and trucks. All too often, however, this results in overly crowded airports and central terminals that can create their own economic problems, along with congestion, pollution, and other environmental hazards. This is particularly true in maritime transport in the era of megaships. Larger container ships certainly

decrease shipping costs for carriers and facilitate global trade. However, they also contribute to overcapacity, require expensive adaptations of infrastructure (often funded by taxpayers), and impose costs on other firms in the freight value chain.

The consolidation of large container volumes in fewer large vessels, for example, causes intense peak time pressure on ports and hinterland transport systems. Port channels must be dredged to ever-greater depths and ports themselves need more cranes, more space in the yard, and the ability to handle more trucks and barges to move the containers inland. [An OECD report](#) estimates that megaships are increasing landside costs by as much as \$400 million a year (a third for extra equipment, a third for dredging, and a third for port infrastructure and hinterland connection costs). Fewer sailings also mean more concentrated supply chain risks and greater susceptibility to disruption from operator errors and external threats. Ship size has become one of the most challenging issues in maritime transport, with repercussions for all.

Airports face similar issues as they grow larger, regardless of whether they are located in developed or developing economies. The lack of slots at major hubs — often constrained for environmental reasons — means that while inhabitants of major cities have the convenience of multiple daily flights to other major cities (in 2016, there were [30 flights each day](#) between London and New York, for example) regional air services from London to smaller communities in the British Isles are being forced out, resulting in those regions becoming disconnected from the global economy. Similarly, the recent air services liberalization within the Association of Southeast Asian Nations (ASEAN) would allow more regional airports to connect to major global airports such as Singapore's Changi and Bangkok's Suvarnabhumi — except that there are no available slots.

- **Demographic and cultural changes.** Some developed countries, such as Japan and Germany, are seeing major changes to their demographic pyramids and workforce structures due to declining birth rates, immigration, and improvements in health and longevity. As a result, more women, mobility-challenged people, and individuals unfamiliar with the local language are using transport systems for both work and other reasons, and they often face greater challenges than do traditional commuters.

Yet many transport systems fail to provide good mobility to passengers outside their core local adult male market, including people with reduced mobility, sight, or hearing; the elderly; women; minorities; and rural inhabitants. [The U.K.'s Parliamentary Office of Science and Technology](#) reports that 57 percent of disabled people in

the country have transportation problems. People in wheelchairs and older people, for instance, have difficulty getting over gaps between platforms and trains and between sidewalks and vehicles. And women using public transport experience unwelcome verbal and physical attention, even paying with their lives for their decision to use the transport system, as recent incidents of rape and murder on Indian transport systems show.

- **Quantifying the unquantifiable.** Traditional transportation appraisals sometimes focus on straightforward calculations of the costs of any new investment versus its economic benefits. As economies change, however, so must approaches to appraisal. There is a pressing need to quantify impacts that have long been analyzed using qualitative techniques alone, such as impacts on quality of life and on society. The effect of transport on where businesses and individuals locate themselves needs to be assessed, as does the distribution of impacts between different areas and groups of people. More rigorous approaches to demand and cost forecasting are required, taking advantage of big data techniques and crowdsourced information on travel patterns.

Challenges in transport planning

In developed economies, planners consider a wide range of factors before committing to a transportation-related investment. However, the consequence is that decisions about urgently needed infrastructure, such as a new runway for London, can take many years. In developing economies, on the other hand, decisions to invest are often made very quickly based on political priorities, resulting in suboptimal outcomes and unintended consequences. As transportation planners in both developing and developed economies grapple with the consequences of growth and new technologies, they must take into account many new and emerging issues.

- **Financing and funding.** Building new transportation systems has always been a financial challenge, and the uncertainties surrounding the nature and design of future transport systems (such as alternative fuels, driverless vehicles, ride sharing, drones, and untested technologies including the high-speed pod known as [Hyperloop](#)) will only increase the difficulties. The public and private sectors must collaborate closely in areas such as risk sharing to facilitate the innovation and financing needed to build truly sustainable transport infrastructure.
- **City and regional transport planning and operations.** How communities operate on a daily basis must be transformed, as massive crowdsourced real-time data becomes available both in normal times and during disruptions. New systems and techniques such as machine learning must be devised to develop and provide value-added accessible services; to radically enhance the quality of planning of new routes, networks, and infrastructure; and to provide advice to individual users as they travel.
- **Road design and traffic management.** The emergence of app-based ride hailing is already resulting in changes to road use patterns, and the adoption of autonomous vehicles will mean even more radical changes to the requirements for car parking, road access, and road use patterns. Commuters, for example, might perform all kinds of tasks in their vehicles while traveling, such as working, eating,

The public and private sectors must collaborate closely to build truly sustainable infrastructure.

napping, exercising, and more. That in turn could spread out the times of peak traffic flow in cities — but it might also result in commuters being happy to travel longer distances, causing further congestion. At the same time, autonomous vehicles may run errands by themselves, again significantly increasing congestion. Determining where to park unused vehicles, defining the most appropriate uses of scarce road space, and prioritizing vehicles with high public value or urgent tasks will be a major challenge for transport system designers and city planners.

- **Rising operating and maintenance costs.** Many public transportation providers are also concerned about increasing operating and maintenance costs. Publicly subsidized transport networks are constrained by annual budgets, so even when investment funds have been allocated, there is often insufficient money available to deliver the optimum level of service. In much of Europe, this is one of the biggest constraints on the expansion of public transport services in terms of frequency and reach. System life-cycle costs must be considered and optimized at the time of making investment decisions — another reason to consider delivery through public–private partnerships.
- **Increasing e-commerce activity.** More and more packages are being delivered by truck, van, motorcycle, and soon autonomous vehicles. Innovative approaches are being proposed to solve this problem, including the use of lockbox systems and delivery drones to reduce road congestion. Yet these solutions, too, may simply lead to new categories of social cost that planners must start to consider.
- **Powering transport systems.** As we move to an increasingly electrified and digital world, the power needed to run our transport infrastructure will shift away from fossil fuels to more sustainable sources of energy. Moreover, the electrical grid itself must be redesigned. Power must be made available in the right place at the right time to charge and operate a wide variety of vehicles, and to take advantage of their ability to store and regenerate electricity themselves.
- **Cybersecurity.** In a world of massively increased connectivity and data sharing, the risk of cyber-attacks is much greater than before. Systems need robust data architectures so that users, freight consignments, and vehicles are adequately protected. Protecting against hacking into or cyber-stealing vehicles, along with shielding data about travelers and freight shipments, must remain a constant concern of manufacturers, operators, and governments alike.

System life-cycle costs must be considered at the time of making investment decisions.

New planning goals

Creating sustainable and inclusive transport systems demands a very different planning model from those that are currently in use in both developed and developing economies. The model for the future will need to be far more flexible, adaptable, and well-regulated. For this profound shift to occur, three new concepts need to be adopted.

- **Distributed and diversified transport systems.** First, systems must be devised that allow for the greater distribution and diversification of transportation. The key is to spread out transportation systems to avoid extreme concentrations of traffic through a few corridors, modes, and high-density nodes, and thus make them significantly less prone to major disruptions. And future systems must also be deeply interconnected, providing wider geographic coverage so that they can be more inclusive and more easily accessed by users, thus mitigating the need for ever more intensive urbanization.

Germany's approach to transport planning is instructive: It takes into account multiple parallel modes of transportation — air, rail, road, tram, bus, bicycle, and pedestrian — combining them into a highly diversified network that provides multiple alternatives and quick access to both high-speed and local transport modes for a high proportion of the country. Germany's model is not directly applicable everywhere: The country has the distinct advantage that its towns and cities are primarily medium-sized. Still, its core principles can be applied at both national and regional levels to enable livable communities that are well provided with transport solutions.

With a very different, much more concentrated economy, the U.K. is making plans for a high-speed rail line that links London more quickly to the major cities of the Midlands and northern England. The motives are both economic and political: to distribute more widely throughout the country the benefits of economic growth in an economy that is currently highly dependent on London, a city having real problems providing adequate and affordable facilities for its growing population.

- **Sharing of real-time data.** The planning and management of transport systems has traditionally involved building new capacity based on historical data extrapolated from discrete trip counts. This approach struggles to account for highly complex, networked transport systems where users have many choices available, and is therefore inadequate for current planning needs (and has long been prone to error, leading to occasional major investment write-offs). Already, thanks to innovations in technology including crowdsourced data and real-time monitoring of road congestion and flows of transport such as shipping containers, data can be made available almost instantaneously that creates new opportunities for the planning and management of deeply integrated, highly efficient, multimodal transport systems, from pedestrian traffic to sea and air transport.

Real-time data is already helping to enable the more efficient use of infrastructure. The U.K.'s "smart motorways," for example, use real-time data to regulate and stabilize traffic flows, warn drivers of congestion ahead, and automatically open additional lanes when the road becomes busy. Already, drivers are making use of crowdsourced data about road conditions to enable real-time route optimization to bypass congested routes. Improved techniques for analyzing big data have the potential to deliver even better planning decisions and real-time operational outcomes that can improve sustainability and inclusivity.

It is critical, however, to ensure that such data is readily shared among all stakeholders. An understanding of traffic flows, communal journeys, and demand for taxi services, for example, can allow transport planners to identify gaps in infrastructure for further improvement, such as where to extend urban rail lines and feeder bus services. Passengers, transport providers, infrastructure operators, and planners and regulators alike can make better-informed decisions if public transport systems and key trip generators, such as shopping malls and parking lots, share usage and availability data.

Indeed, regulators could mandate as part of every licensing regime for all modes of transport that their real-time data on capacity availability and congestion be shared. The potential for innovative uses of such data is enormous. When Transport for New South Wales in Australia brought together a group of app developers and provided them with access to its real-time bus running data, the teams developed and launched several new, privately funded apps supporting the public's use of rail and bus transport systems.

It is critical to ensure that real-time, crowdsourced data is readily shared among all stakeholders.

- **Develop pragmatic, balanced regulatory schemes.** Transport systems are complex networks that require heavy up-front investment but provide value to users and the economy at large over an extended period, in some cases a century or more. That's a trade-off that can make any system's economics difficult to sustain. Most regulatory regimes also seek to strike a balance between the needs of operators and users. But all too often they can be inflexible and biased in one direction or another.

Regulators can be captured by vested interests such as infrastructure operators and lobbies for specific types of transportation, and often do not think in a multimodal way. Indeed, most transport ministries are organized by mode (rail, road, sea, air), making it difficult for them to develop a coordinated policy that factors in the ways people and goods actually travel from point to point, using a variety of transportation modes. And despite the fact that many journeys are partly on foot, the pedestrian is often forgotten, both in developing and developed economies. Public transport planning needs to pay more attention to how to get to and from train stations and bus stops if people are to be enticed away from the comfort of their cars.

Moreover, policies such as cabotage, which restrict the rights of companies to operate freely outside their own base jurisdiction, should be phased out wherever appropriate. In many areas, for example, licensed taxi drivers are forced to make empty return journeys because they are not allowed to pick up passengers outside their own districts. Airports often try to maximize revenue by licensing their own taxis (or granting exclusive concessions), thus increasing congestion, when they would serve the public better with open access systems. In one case, an airport operator opposed a public transport initiative because the new system would reduce its revenue from monopolistic parking charges.

Getting the balance right is critical if regulators are to achieve sustainable and inclusive transport systems. But doing so will require considerable changes in how passenger and freight transport systems are organized and in how society uses them. Some changes will require that governments apply policies to drive collaboration, data sharing, and integrated transport planning. But flexibility is also critical: It is essential that government policies can be adapted to new developments in technology and techniques for using data. The current tension in many cities around the world arising from the use of ride-hailing apps is a case in point: Flexible, outcome-oriented policies must balance the needs of users with those of transport investors and operators to ensure that the systems they have built and run remain economically viable.

Conclusion

In the coming years we will see a technological revolution in transportation that will affect all users, passengers, and freight shippers alike, and will inevitably drive new approaches by regulators, funders, and policymakers. Decisions made now will lock in the future shape of transport, so it is essential that the technologies currently being unleashed are used to ensure that the new transport world will be both sustainable and inclusive. This requires close collaboration by governments, academics, systems developers, investors, and users. Most of all, it requires a clear vision of what a user-centered transport system will look like, what it will take to build it, and how to appraise it in a way that takes into account the total impact of the investments and policies that are under consideration.

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