PRE-PUBLICATION DRAFT – SUBJECT TO REVIEW
11 Feb 2017

Sustainable and inclusive transport systems
A new framework for planners, policy-makers and investors

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Executive Summary

Moving people and goods within and between cities and rural areas efficiently, safely, and sustainably remains a problem begging for new solutions in our increasingly globalized, urbanized, and environmentally compromised world. The old theories and techniques of planners and policy-makers no longer suffice to sort out our ever more complex transport infrastructure. Instead, we must turn to new methods and new technologies if we are to build transport systems that deliver these goals while inclusively functioning to the benefit of all.

The problems are many: Many of the world's urban transport systems cannot meet the needs of rapidly growing populations, and there are few guarantees of safety and security for women and elderly passengers. Planning efforts based solely on limited economic calculations fail to take into account the full consequences to society, or the needs of underserved users. And our current transport systems depend on power sources that account for a significant portion of the greenhouse gases leading to global warming.

If planners are to successfully ameliorate these effects, they must promote collaborative financing between the public and private sectors, build distributed and diversified transport systems to reduce congestion and costs, promote the use of technologies using real-time data as a key tools in both planning and operations, and develop regulatory mechanisms that balance the interests of all transport modes and the needs of all stakeholders.

A world of 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 among the fastest growing. And it is among the cities facing the largest 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, with an improving guided bus network and a limited heavy rail system, is woefully overcrowded, poorly laid out to meet the needs of its population, and perennially subject to changing policies. Passenger flights at Jakarta's airport have doubled over the past 10 years, and the resulting lack of runway capacity has had a significant negative impact on Indonesia's economic growth. Its port, regularly prone to massive delays in transhipment, has been among the least efficient in Asia, though this should change with the recent opening of the New Priok terminal.

Jakarta's hugely overburdened transport infrastructure is only part of the mega-city's problems, which include unmanageable growth, persistent poor air and water quality,

housing shortages and massive flooding. But it is by no means unique in its difficulties: regions around the world also face transport problems—not just mega-cities like Beijing and Mexico City but smaller cities and rural areas, too. Add to that the need to accommodate new technologies like autonomous vehicles and environmental issues centred on climate change, and it fast becomes clear that current approaches to transport planning are unsustainable.

Planners around the world are certainly aware of the massive transport challenges their cities and regions face, and the fact that several overarching megatrends —urbanization, climate change, population growth, shifts in economic power, and technological advancements—will affect the effort to find solutions.[1] And their goals are laudable: to facilitate the movement of people and goods around the world efficiently, safely, and sustainably. Indeed, economic growth and technological development are driving a new revolution in transport. 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 $14 trillion over the ten years from 2016 to 2025.[2]

But simply building more infrastructure, although attractive, is not an adequate solution. The challenge of developing mobility solutions to meet rapidly increasing demand runs into both environmental and economic problems as incremental increases in capacity drive disproportionately greater complexity, cost, and concerns about sustainability. And it is compounded by the fact that anything that does get built will determine the direction of transport flows for decades to come, whilst often moving congestion to the next tightest bottleneck.

Overcoming these challenges will require that planners leave behind their increasingly inadequate analyses of the transport investment trade-off between cost and economic benefit, and turn instead to new, technologically enabled approaches to transport planning and operations. More diversified and widely distributed systems must be built, which are able to optimise travel via the free and transparent movement of data, and align more closely to the needs not just of operators but of users as well. To do so, planners must come to understand, and optimise, the complex trade-offs between the economic, social, environmental, and tax impacts involved in planning any transport infrastructure project, as well as develop new planning tools which can make use of the very rich sources of data emerging from crowd-sourced navigation systems and smart-city solutions.

Growth and its consequences

[1] http://www.pwc.co.uk/issues/megatrends/megatrends-overview.html

[2] http://www.pwc.com/gx/en/industries/capital-projects-infrastructure/publications/cpi-spending-outlook.html

Consider just how quickly the demand for transport of both people and goods is growing, particularly in developing countries. Between 1996 and 2014, container transport by rail in India alone grew 4.4 times, from 700,000 to 3.1 million, while road transport there grew 5.4 times, from 1.4 trillion to 7.6 trillion passenger-kilometres, overtaking the United States during the global financial crisis of 2008[3]. Globally, airline passenger traffic grew 2.3 times, with low and middle income nations increasing 440%, while high income countries only saw a 79% increase. Many developing countries are seeking further benefits from integrated transport. China, for example, has proposed its "One Belt, One Road" initiative, designed to coordinate the building of transport infrastructure among countries along the old Silk Road route across Asia and the Middle East, and into Europe and North Africa, as well as a similar maritime infrastructure initiative throughout Southeast Asia and into East Africa.

Developing economy transport infrastructure, however, is not keeping up with the growth in demand. As a result, congestion is increasing and the economic costs are rising, thanks to inadequate air and sea ports, and road and rail networks. Passenger transportation systems are failing to provide safe, comfortable, and reliable travel in both densely populated urban areas and lower-density rural areas, while unpredictable timetables make it difficult for freight transport to effectively serve just-in-time supply chains.

For example, in the rapidly developing Southeast Asian archipelago (covering the countries of Indonesia, Malaysia, Singapore, Brunei, and the Philippines), rapid economic growth has resulted in an explosion in logistics costs and delays, particularly outside core routes and hubs. Manila's Ninoy Aquino International Airport in the Philippines has virtually no new landing slots and has therefore become a major constraint on air travel growth across the entire country, while the cost of shipping a container from Singapore to Brunei is about the same as shipping one from Singapore to Rotterdam due to the economies of scale of very large container ships.

The demand for transport in advanced economies is not growing at the same rate. Passenger miles travelled on the U.K.'s roads, for example, saw virtually no growth from 1996 to 2014, reflecting government policies to restrain the growth in vehicle traffic due to its environmental impact—an issue that remains a problem in every country around the world. (Despite this, transport systems in developed countries certainly continue to require significant on-going repair, upgrade, and in some cases, expansion.)

The challenging present

Unfortunately, simply building more infrastructure and hoping for the best is no solution to the many problems—economic, social, and environmental—that global transport systems will have to manage as they continue to grow:

- **Environmental and health issues**. The world's cities are responsible for up to 70 percent of the greenhouse gas (GHG) emissions that are driving climate change—

[3] OECD

and transport is responsible for fully 13 percent of that total, 95 percent of it coming from fossil fuels. The air pollution caused by this and other pollutants is clearly linked to negative health effects such as the increased risk of death from respiratory and cardiac conditions. Air pollution in China alone is responsible for the premature deaths of as many as half a million people, and its government is working hard to battle the problem[4]. Planners therefore need to consider how their systems will minimise pollution.

Diseconomies of size. Companies can achieve significant economies of scale by sending their passengers and freight through central hubs and maximising the capacity of ships, aircraft, trains, and trucks. The result, however, is complex and highly concentrated transport systems that can create their own economic problems and exacerbate congestion, pollution, and other environmental impacts—costs that are not typically factored into the cost paid by users.

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, large ships 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 also 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[5] estimates megaships are increasing landside costs by up to $400 million per year (one third for extra equipment, one third for dredging, and one 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[6]. Ship size has become one of the most challenging issues in maritime transport, with repercussions for all.

- **Safety concerns.** Traffic accidents currently claim a global 1.2 million lives annually, and are predicted to 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.* Lack of modern, safe public transport makes people less willing to use it, even as most major cities are growing out, not up, making trips longer, more dangerous, and increasingly unaffordable for the average citizen. Unsustainable transportation also contributes to traffic congestion which further exacerbates delays. In Europe and the U.S. alone, the annual cost of

[4] Chen Zhu together with Wang Jinnan, Ma Guoxia and Zhang Yanshen from the Chinese Ministry of Environmental Protection, The Lancet, December 2013.
[5] OECD/ITF Report on The Impact of Mega-Ships
[6] In Safety and Shipping Review (2016), insurers Allianz estimates the potential cost of an incident involving a 19,000 TEU vessel can reach more than $1 Billion

traffic congestion is expected to total $293 billion by 2030, an increase of almost 50 percent over 2013.[7]

- **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, and people unfamiliar with the local language are using transport systems for both work and other reasons.

  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, females, minorities, and rural populations. A survey conducted by the UK's Department for Work and Pensions shows 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, or the pavement and vehicles. Research by the UN revealed that women using Bogota, Colombia's light rail system during top commuting hours are disproportionally more likely to be victims of robbery than are men. 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.

- **The non-financial impact.** Traditional transport planning focuses on straightforward calculations of the costs of any new investment versus its economic benefits. Cost/benefit analysis, however, has several flaws. It emphasizes the numerical over the qualitative, for example, even though best practice always considers qualitative aspects such as social inclusion. In an increasingly constrained and congested transport environment, basing future estimations of both costs and benefits on historical trends may lead to serious miscalculations and underestimate the social impact of transport.

  In the current planning environment, a much broader list of factors should be taken into account in order to establish the overall benefits of a new transport investment. These should include the impact on various sectors of society (including those with few economic resources) as well as the quality of life of the affected stakeholders.

The challenges of transport planning

[7] https://www.cebr.com/reports/the-future-economic-and-environmental-costs-of-gridlock/

As transport planners grapple with the very real consequences of demand growth and sustainability, they must take into account many new and emerging issues.

- **Financing and funding**: Building new transport 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 like 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 planning and operations:** How communities operate on a daily basis must be transformed, as massive crowd-sourced real-time data becomes available both in normal times and during crises. New systems and techniques, using machine learning for example, must be devised to provide advice to individual users as they travel, to develop and provide value-added accessible services and also to radically enhance the quality of transport planning of new routes, networks and infrastructure.

- **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 travelling, such as working, eating, napping, exercise, and more. That in turn could spread out the times of peak traffic flow in cities—but may 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 causing significantly increased congestion. Determining where to park unused vehicles, defining and prioritising the most appropriate uses of scarce road space, and prioritising vehicles with high value or urgent tasks, will be a major challenge for transport system designers and city planners.[8]

  Increasing ecommerce activity is also exacerbating the "last-mile" problem, as more and more packages are delivered by truck, van, motorcycle and, eventually, by autonomous vehicles. Innovative approaches are being taken to solve this problem, including the use of locker systems and delivery drones to reduce road congestion. (Or will drone congestion simply lead to a new category of social cost?)

- **Provision of power for transport**: As we move to an increasingly electrified and digital world, the power needed to run our transport infrastructure will shift away

[8] .See "Connected car report 2016: Opportunities, risk, and turmoil on the road to autonomous vehicles." http://www.strategyand.pwc.com/reports/connected-car-2016-study. "The era of digitized trucking: Transforming the logistics value chain." http://www.strategyand.pwc.com/reports/era-of-digitized-trucking.

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 rail and road-based vehicles, and to take advantage of their ability to store and generate electricity themselves.

- **Cyber security**: In a world of massively increased connectivity and data sharing, the risk of cyberattacks will be far greater. Systems need to be developed with robust data architecture so that users, freight consignments and vehicles are adequately protected. Protecting against hacking into or cyber-stealing vehicles, and the data, freight, and even people in them, remains a constant concern of manufacturers, operators, and governments.

A new planning paradigm

Clearly, transport systems in most cities and regions as currently structured are not adequate or sustainable for a future that threatens growing usage demands, changing populations, more pollution, a warming climate, but will also benefit from new technologies. Yet planning for the future will be no easy task, given financial restrictions and the competing demands of many stakeholders. Creating a sustainable and inclusive global transport system demands a very different planning model, one that focuses not on the needs of operators and systems, but rather on the end-to-end user experience and the total impact on economies and on society as a whole *(See "An integrated framework" below).* For this profound shift to occur, three new approaches are required:

- **Build 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 our transport systems to avoid extreme concentrations of traffic through a few narrow corridors, modes of transportation, and high-density nodes, and thus make them significantly less prone to major disruptions. And our future systems must also be deeply interconnected, providing wider geographic coverage, and thus more inclusive, more easily accessed by more end users and mitigate the need for ever more intensive urbanisation.

  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 high-speed and local transport modes for a very 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 of medium-size. Still, its core principles can be applied at both a national and regional level to enable liveable communities that are well provided with transport solutions.

  Taking a page from the German model, the UK is making plans for high-speed

rail lines that link London with the country's other major cities. 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 which is having real problems providing adequate and affordable facilities for its growing population.

- **Promote the sharing of real-time data.** The planning and management of transport systems has traditionally relied on historical data extrapolated from discrete counts, which is simply inadequate for current planning needs (and indeed has always been prone to error, leading to occasional major investment write-offs). Already, thanks to innovations in technology such as crowd-sourced data and real-time monitoring by satellite of road congestion and other transport flows such as 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 enabling the more efficient use of infrastructure. Innovations such as smart motorways in the U.K., designed to warn drivers of congestion ahead and automatically open up additional lanes, use real-time data to regulate and stabilise traffic flows, while crowdsourced and satellite data enable real-time route optimisation. Improved techniques for analysing 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 are 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 car-parks, share usage and availability data.

  Indeed, regulators should 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 New South Wales Transport 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 its rail and bus transport systems.

- **Develop pragmatic, balanced regulatory schemes.** Transport systems are complex networks that require heavy upfront investments while at the same time offering value to users and the economy at large over an extended period, in some cases a century or more—a trade-off that often makes the system's economics

unsustainable by itself. Most regulatory regimes seek to strike a balance between the needs of operators and users. But they can be inflexible and biased in one direction or another.

All too often, regulators can be captured by vested interests such as infrastructure operators or transport mode lobbies, and often do not think in a multi-modal way. Indeed, most transport ministries are organised by mode (rail, road, sea, air), making it difficult for them to think about how people and goods actually travel from point to point, using a variety of transport modes. And despite the fact that most journeys are partly on foot, the pedestrian is often forgotten, especially in developing economies. Public transport planning needs to pay more attention to how to get to and from stations and bus stops if people are to be enticed away from the comfort of their cars.

Moreover, old-fashioned policies such as cabotage, which restrict the rights of companies to operate freely in various locations, must be phased out wherever possible. In many jurisdictions, for example, licensed taxi drivers are forced to make wasteful empty journeys because they are not allowed to pick up passengers outside their own districts. Airports often try to maximise revenue by licensing their own taxis (or granting exclusive concessions), thus increasing congestion, when, as a monopoly, they should have open access systems. In one case, an airport operator opposed a public transport initiative because this would reduce its revenue from monopolistic car parking charges. Contrast Indonesia, where airport parking is regulated by the local authority and parking charges are low—although this can also be problematic as people have no incentive to use public transport.

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 organised 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 key: it is essential that government policies are flexible enough to adapt 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 the 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 complete transport revolution—new vehicles, new technologies, new systems—that will affect every transport user, whether passenger or freight shipper, as well as regulators, funders, and policy-makers. Decisions made in the coming years will lock in the future shape of transport, so it is essential that the

technology currently being unleashed is 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 end-users, and most of all, a clear vision of what a global user-centred transport system will look like, and what it will take to build it.

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An integrated framework

Planning for even the simplest form of transport—laying out a proposed route for bicycle paths in a city neighbourhood, for instance—is a difficult task. 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 factors bear heavily on the success of even the best-laid plans. Nowadays, no planning effort should be embarked upon without some guiding principle that takes into account these factors.

To that end, we have developed the Total Impact Measurement and Management (TIMM) framework, with the goal of helping policy makers and planners understand the myriad trade-offs that come into play when planning any transport infrastructure project, and to identify the options that will drive the optimal outcome and result in a sustainable transport system that considers the needs of all stakeholders.

Exhibit A illustrates how the framework works. The grey circle lists all the potential stakeholders in any investment, while surrounding that are the four impacts that investments will invariably have.

- **Economic.** Economic impact measurement measures the effect of a given transport policy or plan on a city or region's economy. It measures the potential for changes in economic growth (output or value added) and associated changes in employment, productivity, and the like. Some elements of it (e.g. multiplier analysis) are fairly well established.
- **Social.** Social impact analysis measures and values the consequences of investments on societal outcomes such as health, education, safety, and community cohesion.
- **Environmental.** Environmental impact analysis measures emissions to air, land and water, and the use of natural resources, and then puts a value on the resulting impacts on society.
- **Tax.** Tax impact measurement identifies and measures a transport investment's overall contribution to the tax base, using a well-established process such as the Total Tax Contribution framework.[9]

Circling the ring of impacts are the specific effects any investment will have—on air and water pollution and land use in the case of environmental impacts, for example. The

[9] http://www.pwc.com/gx/en/services/tax/publications/total-tax-contribution-framework.html

length of each of these lines indicates the size of the impact; green lines indicate positive impacts while red lines are negative. To use the framework, planners must assess the actual size of each impact, and then aggregate them to arrive at the total effect.

Exhibit A. The Total Impact Measurement and Management (TIMM) framework—a hypothetical example.