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Research Article

Review of Approaches to Enhancing the Effectiveness of Transport Infrastructure and Services: A Focus on Asia

Karlson Hargroves[1, *], Peter Newman[1], Ganesh Raj Joshi[2], Benjamin James[1]

[1]Curtin University Sustainability Policy Institute, Perth, Australia

[2]United Nations Centre for Regional Development, Nagoya, Japan

Abstract

A dominance of private vehicles in cities around the world has led to unsustainable levels of congestion, pollution, and human harm, which stand to be exacerbated by future growth. This paper briefly outlines the implications of rapid urbanization based on private vehicles and then provides an overview of the benefits associated with Integrated Shared Transit (IST) services. IST can provide a number of benefits such as improved public health outcomes, reduced congestion, and reduced land use from car parking, along with economic development and job creation Opportunities. A recent study suggested this approach presents strong local economic multipliers with every US$1 invested in shared transit creating as much as US$4 in economic returns. The paper then provides a review of four important areas, namely: the shift to electro-mobility, the creation of transit activated corridors (TACs), advanced freight telematics exchange, and the use of disruptive technologies including artificial intelligence and distributed ledgers. The paper then concludes with the recommendation to shift focus from a model of private vehicle dominance to a system of integrated shared transit that is supported by private modes.

Keywords

Shared Transit, Electromobility, Transit-Activated Corridors, Telematics, Artificial Intelligence, Distributed Ledgers

1. Introduction

The transport system in many growing cities around the world has often been focused on the provision of infrastructure for private vehicles, with this approach proving to be problematic as cities struggling to accommodate increased numbers of vehicles on the road. This situation is expected to worsen in light of predicted levels of growth in the future, especially in Asia. According to the United Nations, it is expected that an extra 2.4 billion people will be added to the world's cities by 2050 [1]. The Asian Development Bank estimates that 44 million people will be added to cities in Asia each year. [2] It is likely that this rapid growth in urbanization will see an increase in demand for transport services by 2.6 times around the world up to 2050, [3] with annual passenger traffic set it exceed some 80 trillion passenger-kilometers. [4]

To meet increasing demand, the level of private car ownership will see a five-fold increase in nations outside of the OECD by 2050. [5] This growth in private vehicles can not be sustainable due to the physical land constraints of cities and associated environmental and social implications. This means that there is a need to focus on effective shared modes. If this

*Corresponding author: 249711k@curtin.edu.au (Karlson Hargroves)

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is done effectively, a focus on shared options can reduce congestion, lower pollution levels, and reduce resulting human harm, while delivering economic, social and environmental benefits. [6]

1.1. Implications of Rapid Urbanization

There is a set of well-established issues related to the dependance on private vehicles with the following providing a succinct summary with recent evidence.

1) *Congestion Costs*: A report by the Boston Consulting Group suggested that residents in India's largest cities, including Delhi, Mumbai, Bengaluru and Kolkata, experience 1.5 hour longer commutes when compared to other similar Asian cities, which results in direct costs in the order of US$22 billion per year. [7]
2) *Air pollution*: In 2021 a study found that air pollution had contributed to the death of over 10 million people each year, [8] with the WHO suggesting that some 90 percent of air pollution related deaths currently take place in developing countries, and cost over US$5 trillion globally in welfare losses. [9] A similar study by the OECD suggests that this cost will increase to US$25 trillion by 2060. [10] Mega cities in Asia are experiencing severe air pollution conditions, for instance Delhi experiences 11.5 times the WHO recommended PM2.5 levels, Dhaka experiences 9.7 times, and Beijing experiences 5 times the recommended levels. [11] According to a report by the UNCRD, The cost of air pollution related health impacts is in the order of US$1 billion a year in cities, including Bangkok and Jakarta, with air pollution related costs in the order of 2 to 4 percent of their GDP annually. [12]
3) *Road Injury and Fatalities*: According to the WHO, some 1.3 million people die due to road traffic-related incidents around the world each year. [13] According to UNESCAP, over 60 percent of global road fatalities take place in the Asia-Pacific region, despite the fact that the region has 16 percent of the global vehicle fleet. [14] The World Bank predicted that if countries including China, India, Thailand, and the Philippines reduce road traffic deaths and injuries by 50 percent this would result in a saving of 7.2 percent of national GDP in the Philippines, 14 percent in India, 15 percent in P.R. China, and 22.2 percent in Thailand. [15]
4) *Climate Change*: A 2021 SwissRe report projected that climate change stands to cost the global economy in the order of $23 trillion by 2050, equivalent to one-fourth of the world's GDP. [16] However for South Asian developing countries that are most affected by climate change the loss could be up to 11 percent of their GDP by the end of the century. [17] In the case of India, projects suggest losses of up to US$13.8 billion annually due to the impacts of climate change. [18]

A key part of the reduction of the use of private vehicles, and the associated economic, social and environmental issues, will be the electrification of vehicles such as bicycles, shuttles, buses, trams, and trains. This calls for new approaches to integrated shared transit provision, such as the creation interconnected multi-modal transport networks, managed in such a sway as to offer seamless service information, provision, and ticketing. [19]

1.2. Benefits of Integrated Shared Transit (IST)

According to the Asian Development Bank, to achieve sustainable urban development and improved economic growth, developing countries will on average need to invest in the order of US$26 trillion in infrastructure by 2030 at the rate of US$1.7 trillion per year. [20] If undertaken effectively there will be a number of opportunities to meet transport needs in a way that creates multiple benefits, such as: [21]

1. *Health-Related Benefits*: Vehicle emissions, particularly diesel or two-stroke engine vehicles, is recognized as one of the highest contributors to air pollution in urban areas in Asian countries. [22] Based on 2016 data, the World Health Organisation (WHO) stated that 4 in 5 people who are living in monitored urban locations are exposed to air pollution that exceeds recommended levels, and further that 98 percent of low-and-middle income cities with over 100,000 people don't meet the air quality guidelines. [23] If cities can find ways to reduce the focus on private vehicle infrastructure and look to ways to create integrated shared transit this can reduce the number of overall vehicles on the road, and the associated emissions.
2. *Overcoming Congestion Issues*: In many cities around the world the levels of traffic congestion has become unworkable which calls for alternatives to be explored rather than a continued focus on private cars. [24] Given the issues related to congestion such as spent time, air pollution, and the emissions of greenhouse gases, it makes sense to take advantage of higher capacity options where practical. For instance, the Hong Kong rail line provides a capacity of 86,000 people per hour with services of 12 rail cars running every 2.5 minutes, providing a strong case study to inform similar efforts. [25] When combined with a range of emerging technologies such options become more beneficial, such as reducing operating costs by adopting driverless technologies, battery energy storage, predictive maintenance, Web 3.0 ticketing, and trackless trams. [26]
3. *Reducing the Need for Car Parking*: According to a global study by Newman and Kenworthy in 1999, cities that are car dependent often have between 5 and 8 car parking spaces for each car. [27] This means that as car numbers increase the amount of land needed for provision of parking also increases, causing issues in already heavily developed urban areas. The International Energy Agency estimates that s that India is on track to need as

much as 20,000 square kilometers of surface parking area, equating to 35 times the size of Mumbai by 2050. [28] A strategy to provide shared transit services can reduce this requirement, especially in central city locations, by offering access to corridor based station precincts with a range of attractions and services.

Providing better access to shared, efficient, reliable, affordable, and sustainable transport infrastructure and services is a key part of poverty eradication, economic growth, social and community development, and increasing the level of resilience in cities and communities. [29] For instance as incomes rise, integrated shared transit will support and promote a range of business activities. [30] The economic multipliers associated with investment in such transit reach pasts those that use it, with a 2020 American Public Transportation Association study suggesting that for every US$1 invested as much as US$4 is created in economic returns. [31]

2. Key Areas of Focus for Integrated Shared Transit

1) The Shift to Electro-Mobility

In recent times there has been significant growth in the availability of electric vehicles of various types due to improvements in battery technology that stand to revolutionize the design of most vehicles. Early movers typically focused on smaller modes, such as scooters and bicycles, and then moving to private vehicles, with the focus now moving to heavy vehicles. Hybrid internal combustion and battery powered vehicles provide a transition option for those that want to buy an EV while being able to fill up the vehicle as usual. This transition technology can allow time to shift a nation's energy economy from a focus on physical fuels to a focus on electricity over the medium term, with many local economic, social, and environmental benefits. Such a transition can have major implications for cities around Asia because the electrification of vehicles not only significantly reduces air pollution, but also provides the opportunity for innovative new energy industries to grow and deploy decentralized renewable energy options. [32]

For instance, the Shenzhen Bus Group has over 6,000 buses and 5,000 electric taxis and is the first fully electric bus fleet in the world, The group has found that not only does electrification reduce running costs of the vehicles, but it can also create new revenue streams. For instance, by installing charging facilities across the city for its fleet has created a lucrative opportunity to offer charging and maintenance services to other electric vehicles such as garbage trucks, taxis, and private vehicles. [33] The provision of charging facilities is a key question for cities around the world as they consider how to best underpin a transition to electro-mobility and explore ways to provide supporting infrastructure.

The transition to electro-mobility enabled cities calls for the creation of new systems and approaches not previously considered. For instance, vehicles need to be able to interact with the electricity grid in a way that is beneficial for both vehicle owners and grid managers. [34] If this interaction is managed appropriately it will create a range of benefits for electric vehicle owners, such as reduced maintenance and running costs, [35] along with the potential to power homes and other load, especially during times of high electricity prices. [36] For government agencies, there is a range of economic benefits, such as new tax and tariff structures, new forms of road user charging, direct revenue from grid services provided by government fleets, data utilization options, park-and-ride charging options, and second-life revenue from decommissioned batteries, along with improving job creation, industry growth, green investment credentials, and energy security. [37]

Governments around the world are considering a range of regulatory frameworks in order to underpin electro-mobility and capture new opportunities. For instance, as of 2020 the EU has set a requirement that new cars registered must emit less than 95 grams of carbon dioxide per kilometer, otherwise, the manufacturer will be fined €95 per gram per kilometer over the limit. If this requirement was in place in 2019 this would have generated in the order of €34 billion in fines. [38] As part of comprehensive approach such fines are able to be offset by selling EVs, and other approved low emissions vehicles, that earn the manufacturer credits, providing a meaningful incentive. [39] Nations are increasingly using taxation and other mechanisms to actively discourage internal combustion engine vehicles. For instance, since 2001 the UK has imposed specific taxation levels based on a vehicle's CO_2 emissions. [40]

2) Transit Activated Corridors (TACs)

A key focus for cities around the world, in particular across the Asian region, is to seek to build on from the success of 'Transit Oriented Development', or TODs, which is focused on providing car parking at transit stations and is intended to help transform rail policy; to the creation of 'Transit Activated Corridors', or TACs, which are focused on creating an integrated corridor of station precincts with the intention to transform road policy. [41] Partially due to the availability of cost-effective options for shared transit that are suitable for application in main road corridors. For instance, innovations in electro-mobility, driver-less technologies, precision autonomous tracking, and high-speed carriage stabilization have been combined to create the ‘Trackless Tram’. [42] Shared transit vehicles like the trackless tram can be used as the backbone of a corridor transit service that activates new developments to create station precincts at a fraction of the price of rail-based options.

A Trackless Tram is effectively a combination of the most effective aspects of a bus merged with that of light and heavy rail. The resulting vehicle is a tram that runs on rubber tires (avoiding disruption and costs associated with the construction of in-road rail systems); harnesses high-speed rail stabilization technologies to deliver a smooth ride on suitable road surfaces; and is powered on-board batteries that are charged at stations and depots, avoiding the need for costly overhead cables. Such a corridor system can be complimented by a range of 'last mile' options such as walking and bicycle paths, shuttles, and micro-mobility modes, which can be integrated into urban corridors to underpin quality urban development in and around stations. [43]

Another difference to standard approaches to public transport is that instead of being seen as the responsibility of government, as in the case of most TODs, the delivery of a TAC is undertaken in partnership with the private sector as it provides a strong basis for effective for public and private partnerships. [44] As with most transport options, corridor transit systems require financial investment with fixed-line systems, such as a light rail or trackless tram, being more attractive to investors than a bus system. [45] This is because a fixed line system is designed to include substantive stations that are unlikely to move, unlike a bus stop or route which is easy to move. [46] This means that a long-term regular flow of passengers is more likely to be created at a set of fixed station precincts which is of value to developers and businesses surrounding each station.

In the past however, changes in land value have largely been captured last, with transport agencies deciding on the location of the route and the stations, followed by municipal governments increasing land taxes and rates for those located near new stations to recover capital – typically without engagement. In principle this type of 'value capture' presents a sound approach, however results have been mixed. [47] Imposing greater costs to those business and residents located near stations is often politically unacceptable with higher costs stifling future land development ambitions.

Newman *et al* proposed the revival of an approach that has been used across Asia to leverage land value that is associated with improved transport services by encouraging new land development along transit corridors as part of an 'Entrepreneur Transit Model'. [47] The model is based on the assumption that viable methods for financing new corridor transit can be based on establishing partnerships between government, developers, and financial institutions to leverage land 'Value Creation' from the start of the project, rather than relying on imposed 'Value Capture' mechanisms to re-coop costs after. [48]

This is achieved by carefully selecting route and station locations that deliver transit services to the community while also increasing the value of specifically chosen land parcels to be developed as part of station precincts. The important thing is to cultivate entrepreneurial approaches that bring transport and land agencies together to actively partner with the private sector in order to deliver transit services and enhanced land development opportunities – with each complimenting each-other.

This approach has been shown to leverage funding, assuming land is acquired at 'pre-transit' prices, and that the transit service delivers the anticipated level of patronage to generate an acceptable level of value for developments around the stations. [41] Furthermore, studies suggest that this type of value creation is not just shifting land developments from one part of a city to another, but due to the corridor approach, it can create value across the urban system that would not have been created without such investment and infrastructure. [49]

3) Freight Vehicle Data and Telematics Exchange

A key element of the transport system for a city is the freight network which often shares infrastructure with private vehicle users. A focus on the development of Transit Activate Corridors will be to service growing station precincts with goods utilizing the freight network. This may involve trucks and small vans, or even as part of corridor transit services with freight carriages used in the transit system. Due to 'shelter-at-home' conditions and other restrictions in response to COVID-19 the freight and logistics sector saw a swift shift in consumer behaviors which had implications, especially for essential cargo requirements. [50] Flow on effects from the pandemic include an increased shipping demands, increased online shopping, decrease in retail loyalty (with up to 70 percent of consumers estimated to have tried alternatives [51]) and, according to the European Commission, an increase in quantity and importance of essential cargo delivery to aid in crisis relief. [52]

In 2017 the Global Mobility Report predicted that freight volumes would grow by 70 percent up to 2030. [4] According to the International Transport Forum in 2021 global freight demand was set to increase three-fold by 2050 in as usual business scenario, despite the slowdown associated with COVID-19. [3] This increase in freight demand will flow on to create increased urban and rural traffic management demands which will put additional pressure on infrastructure globally. Robust, well managed and sustainable transport infrastructure such as shared transport systems, highways, railways, airports, seaports, and related services play key role in improving transport options. Nevertheless, the major challenge for the Asian developing countries is how to accommodate the future transport and freight demand as the majority of Asian cities are already over-congested and will continue to struggle to manage continued private vehicle growth. [29]

Given the high value of freight, much attention has been paid to identifying ways to increase the efficiency of freight movement. However, on the whole, the limited technical knowhow and capacity of both the freight sector and the transport system itself has meant that such efforts are yet to demonstrate meaningful improvements. [53] Early approaches that have been explored include freight vehicles being equipped with GPS guidance systems to provide information to the driver on the level of congestion along potential routes. [54] It is now common from logistics companies to take advantage of tracking and analytics services that monitor vehicle locations to ensure the use of approved routes and monitor driver behavior, such as hash breaking or exceeding speed limits. Although such passive approaches do stand to deliver some benefits, their impact is restrained because of a lack of interaction with the transport management system itself. [53]

Efforts have also been focused on investigating the potential for freight vehicles to interact directly with traffic lights to gain priority signaling at intersections, in a similar way to emergency vehicles. [55] The intention is to detect freight vehicles approaching intersections to avoid the vehicle having to stop by extending the green signal. [56] Early trials based on simulations have shown that there is potential for improvement at the intersection level, [57] however it is not clear if this translates into reduced overall trip times. This is because it is likely that ad hoc responses by individual traffic lights that detect the last-minute presence of a heavy vehicle can have a detrimental impact on the effectiveness of system-wide signaling. [58] Hence unlike the movement of a small number of emergency vehicles across an entire city this approach may not deliver benefits when applied to numerous freight vehicles moving across a transport network, calling for a more dynamic approach, one that will involve new forms of data exchange and the use of advanced computational methods.

Often transport agencies rely on periodic manual surveys to provide vehicle movement data as the basis of managing current traffic and planning for future demand. [54] This approach is limited, however it is often utilized due to a reluctance by the private sector to share data with government transport agencies. [53] This suggests that there is a need for the private sector to be able to safely share data in near-real-time with transport agencies, however, this may call for the development of new types of trusted exchange mechanisms. An impact of the current inability to synchronize freight vehicle data with the transport management system means that freight vehicles can be effectively invisible to the system, leaving them to use third-party apps in order to navigate traffic. However, before such an exchange can be possible a number of concerns need to be addressed such as what real value will this create for companies, who will have access to the data, and how will it be used. For instance, can the data be limited to use only by the transport system or will it be open to use by enforcement agencies. [53]

Findings from an Australian industry-based research study that piloted a “Freight Observatory” model to allow for trusted data sharing suggest that “*providing a trusted mechanism to share data with government agencies is a big step forward, however in order to secure data sharing there needs to be sufficient detail around the resulting benefits, beyond longer-term system-wide benefits, particularly for small freight operators*”. [59] The lack of clarity around direct benefits to freight and logistics operators remains a challenge in the current digital system where such data is difficult to leverage without providing ownership to a third party.

One promising area of digital trust is distributed ledger, or Blockchain, technology, as will be further discussed, which can provide a shared digital system that acts as a trusted digital intermediary which does not require an organization or government agency to manage or control it. [60] These types of systems can provide trust along with streamlining transactions between parties, especially along supply chains, reducing delays and providing data authenticity and verification – the kinds of Web 3.0 benefits are not accessible in the current system. [60]

The freight sector now has more opportunities than ever to harness technology to increase productivity, streamline transactions, and enhance traffic management for mutual benefit. [61] Hence it will be important for freight vehicles to be effectively managed in order to deliver benefits for transport agencies, private sector logistics companies, and the road-using public. Better freight management reduces congestion, leading to less pollution and a range of direct and indirect economic benefits. [54]

4) Artificial Intelligence and Distributed Ledgers

Although a focus on Artificial Intelligence is not new there are a number of new and yet to be realized applications that provide new opportunities for the transport sector, such as the following examples as investigated by the Sustainable Built Environment National Research Centre (SBEnrc) in Australia. [62]

1. *Better Traffic Management*: The ‘Malaysia City Brain’ created by Alibaba uses Artificial Intelligence to process traffic light data, CCTV cameras, shared transport, and other data stream, to reduce traffic congestion and direct emergency services. [63] Deployed in Hangzhou China the system resulted in an average 15 percent increase in vehicle speed and traffic violations were reported with 92 percent accuracy. [64]
2. *Traffic Signal Optimization*: The application of Artificial Intelligence to optimize traffic signaling is in its early stages and delivering a system that can allow for variations in real-time comes with challenges as such programs need to learn favorable traffic light cycles and timings. [65]
3. *Vehicle Prioritization*: The 'Public Transport Information and Priority System' in Sydney can detect if a bus is more than 2 minutes behind schedule and provide priority signaling. A 2001 trial on the Sydney Airport Express Bus showed a reduction in travel time of 21 percent and reduced variability of travel time by 49 percent. [66]
4. *Route Optimization*: Logistics company UPS has created an AI system called ORION (On-road Integrated Optimization and Navigation) which identifies the most efficient routes for its fleet based on customer, driver, and vehicle data, with routes updated in real time depending on road conditions and other factors. [67]
5. *Self-Driving* Vehicles: Developed by Cornell University, ‘DeepTraffic’ is a computer program using neural network technology to simulate self-driving vehicles at varying speeds in dense traffic conditions to identify efficient vehicle movement patterns to avoid collisions. [68]
6. *Ride-Sharing*: German company Door2door has created

an on-demand ride-sharing service that uses AI to optimize pooling configurations and routes to simulate demand and respond in real time, while managing dispatches, bookings, route planning, and drivers. [69]

Another example of new technologies is the development of distributed ledger technologies, with one of the most promising referred to as a 'Blockchain'. Blockchain technology has a number of tangible applications to transport such as supporting the increased uptake of automated vehicles, ride-sharing, and pay-as-you-drive options, along with improved management of congestion, freight and logistics, and administrative processes such as licensing and vehicle ownership. The application of Blockchain to the transport sector is likely to dominate future innovative technology efforts as the initial benefits of its use are realized in a number of sectors. [60]

3. Conclusions

The level of dominance of cars in the world's cities has grown to unsustainable levels and efforts need to be focused on providing safe, effective and convenient shared transit services which are complimented by private vehicles and a range of active modes. A central element of an agenda to reduce the dominance of private vehicles, and the associated issues, will be the continued electrification of vehicles such as bicycles, shuttles, buses, trams, and trains to be used as part of an integrated shared transit and freight systems.

Such vehicles can then be used as part of integrated shared transit systems to provide transit services in cities that can activate new development opportunities and revitalize cities. These services provide the opportunity to aggregate activity around station precincts that are connected by corridor transit, referred to as a Transit Activated Corridor, or TAC (building on the previous approach to create Transit Oriented Developments, or TODs). This approach focuses on finding synergies between opportunities for land development and the provision of transit services to create mutually reinforcing benefits. Although such an approach will require capital investment this can be undertaken as a collaboration between the private and public sectors with suitable precedent now established for such an approach.

Taking a Transit Activated Corridor approach also creates the context and setting for the application of a range of emerging disruptive technologies. Recent advances in technology, such as the shift to electro-mobility and the development of distributed ledgers and artificial intelligence, have created a set of new and promising use cases for the transport sector. Advances in vehicle telematics and data exchange platforms also create the potential for advances in traffic management, however it is likely that trusted digital platforms such as distributed ledgers will be needed to overcome the unwillingness to share data in the sector, while streamlining digital transactions. Such technology not only stands to disrupt current practices, but if well prepared for can solve a number of current problems while creating a range of new opportunities, especially for early movers.

In particular, the shift to electro-mobility stands to be a catalyst for great change in both the transport and energy sectors around the world. If old approaches are applied to this new technology, it may again see a spur in private vehicle ownership, especially if vehicles become driverless, however, new integrated approaches stand to deliver greater value. Harnessing the potential of electro-mobility to create lower-cost options for corridor transit, such as Trackless Trams, stands to reshape the financial metrics around urban transport systems making such systems more accessible to developing nations.

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Conflicts of Interest

The authors declare no conflicts of interest.

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