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Urban Public Transport: Planning Principles and Emerging Practice

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Abstract

This article reviews the literature on current "best practice" principles for planning public transport (PT) networks within the context of planners seeking to transition their cities toward sustainable mobility. An overview is provided of the history of ideas about network development. The emerging frontiers for multimodal, demand-responsive PT and the potential implications of new transport technology on traditional PT are discussed. The future role of transit-oriented development within PT network structures is considered. The "moderators" to network design that may impede future best practice brings the article to conclusion.

Keywords

public transportation, urban development, sustainable mobility, transit-oriented development, land use transport integration, network design, urban mobility, on-demand transport, sustainable transport, network reform

As the global renaissance of urban public transport (PT) continues, consensus among researchers for what constitutes "best practice" in network design has broadly been reached. Intermodal connectivity, provision of high-quality services, clear strategic congruency, and integration of transportation and land use policy continue as unambiguous principles in contemporary transport planning practice (Mees 2000; Nielsen et al. 2005; Te Brömmelstroet and Bertolini 2009). However, the progress to transition cities toward sustainable mobility by increasing PT accessibility has been mixed; the result of some players affording these goals greater priority than others (Walker 2008; Curtis and Low 2012). On the near horizon, novel forms of transport may substantially alter passenger transportation in cities.

PT's role as a catalytic support for urban development is now well recognized in the era of sustainable urban mobility (Banister 2005). Sustainable urban mobility typically describes movement patterns or city transport networks which are energy efficient, utilizing active travel modes, renewable forms of energy, or shared vehicles wherever possible, resulting in low carbon output per passenger journey (Banister 2005). As cities contemplate new PT projects, identifying what constitutes best practice in network development will provide guidance for policy makers seeking to improve the sustainability of their cities (Macmillen and Stead 2014; Nielsen et al. 2005). In the decades since the 1980s, integrated, multimodal networked public systems have emerged as a mobility paradigm, utilizing transfer potential to provide maximal service for a reasonable and efficient operating budget, providing a genuinely feasible alternative to the private car for many trips within urban areas (Goodwin et al. 1991).

This article maps the consensus on the planning principles for PT network design and plots future trajectories in urban passenger transportation planning, reflecting on theoretical and evaluative research to inform the next wave of practice. After discussing the methods used to review relevant literature, we explore the historical evolution of PT systems and their governance, key traits of network design and multimodality of PT systems, the emergence of new multimodal transportation technologies, the relationship of PT design with land use planning, and finally issues of implementation.

Method

A systematic literature search for peer-reviewed publications was conducted, focusing on PT network design, future transportation trends, and the political processes of transport policy change. Initially, searches for key terms (Table 1) were made in major journals in the transportation and urban planning fields, where possible limited to results published in the years 2005–2016 inclusive (Table 2).

Search terms were adjusted where journals related to a specific topic, such as land use, or PT operations. Once key highly informative papers were identified, forward and backward

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Table 1. Search Terms.

Search Terms	Total Hits
Public transport* system design	1,935
Public transport* system improvement	1,085
Public transport* network planning	3,374
Public transport* network design	4,756
Mass transit reform	86
System expansion (within public transportation-specific journals only)	1
Best practice rail	481
"Land use" "public transport"	185
Self-driving	483
Autonomous vehicle	70
Public transport*network "land use" + planning	125

Note: The asterisk (*) wildcard is used to yield results with "transport" and "transportation" terminologies.

snowballing was used for references to and in highly influential publications (Van Wee and Banister 2016, 284). Recent conference proceedings (World Congress Transport Research, European Transport Forum; Australian Transport Research Forum; and State of Australian Cities) were also reviewed to identify recent insights and innovations from researchers and industry practitioners.

To ensure a comprehensive search, large databases (Google Scholar, Scopus, and Science Direct) were interrogated for other potentially relevant sources and context materials for case studies of PT improvement projects. The publication histories of authors who featured prominently in search results (Currie, G., Curtis, C., Hickman, R, Litman, T., Mees, P., Murray, C., Stone, J., van Wee, B., Vuchic, V., Walker, J., and White, P.) were examined for any additional relevant works. Publications that focused only on regional intercity transport were excluded, given our focus on urban PT. In all, 236 publications were reviewed for the preparation of this article.

Historical Evolution of PT Systems and Their Governance

In the first part of this article, the history and resulting structure of PT in the twentieth century is described, and a diametric comparison between contrasting organizational types made.

There is a significant diversity in the establishment and characteristics of urban PT networks around the world, dictated by their urban growth periods and investment plans relative to the prevailing PT technology of the time. In the rapidly industrializing cities of the nineteenth century and early twentieth century, tram or streetcar systems, in larger cities supplemented by heavy rail, became the mainstay of urban mobility and exercised a critical influence on the growth patterns of cities (Newman and Kenworthy 2015). After World War I, buses and trolleybuses became more common and, particularly after 1945, replaced tram systems in most of North America, the United Kingdom (UK), France, Australia, and New Zealand. In other continental European countries and the (former) Soviet Union, many tram networks survived and now form the backbone of mixed light rail and bus networks. Since the 1970s, numerous Western cities where PT had become bus-dominated reintroduced light and/or heavy rail systems, most notably in France, Spain, the United States, and Canada (Vuchic 2007, 433). In recent decades, PT has featured as a cornerstone of inner-city renaissances and redevelopment projects internationally (Cervero and Dai 2014).

The globally diverse histories of urban transit in cities have resulted in a considerable variety of system ownership and management structures. The fragmentation or consolidation of organizational control (Curtis and Low 2012), and the regulatory and operational arrangements that arise from them, is a key differentiating factor of PT systems globally (Nielsen et al. 2005, 31). Often, this contrast is most obvious where services are either publicly controlled, or regulated through a single agency, or provided by individual organizations competing within a competitive market (Mees 2000, 101; Fiorio, Florio, and Perucca 2013). In the nineteenth century, it was common for PT operators to be private entities and to engage in integrated economies of infrastructure construction, transit operation, and land development (Mees 2000, 257). During World War I and the economic crises that followed it, many such private operators struggled and, in continental Europe, Canada, and Australia, commonly moved into public ownership so their essential service to the community could be maintained independently of commercial considerations and fares controlled for social equity. In the United States and the UK, nationalization generally did not occur until after 1945, when cities started adapting to the automobile and PT lost significant market share to private vehicles (Gwilliam and van de Velde 1990). Since the 1970s, and partially in response to competition from cars, it has become common for PT operators of different jurisdictions or government tiers to coordinate or integrate their fares, services, and planning in regional transit associations in order to achieve greater efficiencies and present a more user-friendly interface to the public (Pucher and Kurth 1995). Since the 1980s, a renewed trend toward privatization of the PT industry has seen the re-emergence of private operators particularly in Europe and Australasia (White 1995, 1997). Outside the UK, however, these private players generally continue to operate under the coordination of regional transit agencies and have a role in service delivery rather than in configuring the network.

Today's resulting systems can be assessed on a spectrum, based upon their degree of formalized central control. In many cases, the degree of such control also extends to the realm of land use planning. At either end of this spectrum sits the archetypal model of network governance type—the "free market" and the "centrally planned."

The free market model is characterized by the presence of informal, multiprovider systems; where a large number of providers compete in a deregulated market, operating individual vehicles, lines, or on-demand transportation services. Services may range from owner-operated "paratransit" jitneys to entire bus or subway systems (Del Mistro and Behrens 2015). Lines are likely planned to cater for the most profitable demand, with no necessary consideration for broader network context,

Table 2. Journal Searches.

Journal/Database	Period	Search Term	Hits
Applied Geography	2005–2016	Land use public transport	185
Applied Geography	2005–2016	Mass transit reform	2
Applied Geography	2005–2016	Public transport network design	131
Applied Geography	2005–2016	Public transport system design	131
Australian Planner	All	"Public transport" network	331
Case Studies on Transport Policy	2005–2016	Best practice rail	481
Case Studies on Transport Policy	All	Public transport* network planning	59
Cities	2005–2016	Mass transit reform	25
Cities	2005–2016	Public transport network design	250
Futures	2005–2016	"Public transport"	159
Futures	2005–2016	Public transport network design	133
Journal of the American Planning Association	All	Public transport network design	785
Journal of Public Transportation	2002–2016	Best practice	153
Journal of Public Transportation	2002–2016	Public transport network design	186
Journal of Public Transportation	2002–2016	Public transport planning	288
Journal of Transport and Land Use	2008–2016	Autonomous vehicle	0
Journal of Transport and Land Use	2008–2016	Mass transit reform	0
Journal of Transport and Land Use	2008–2016	Public transport network design	0
Journal of Transport and Land Use	2008–2016	Public transport system design	1
Journal of Transport and Land Use	2008–2016	Public transport system improvement	3
Journal of Transport and Land Use	2008–2016	System expansion	1
Journal of Transport Geography	2005–2016	Autonomous vehicle	44
Journal of Transport Geography	2005–2016	Mass transit reform	23
Journal of Transport Geography	2005–2016	Public transport network design	547
Journal of Transport Geography	2005–2016	Public transport system design	593
Journal of Transport Geography	2005–2016	Public transport system improvement	610
Journal of Transport Geography	2005–2016	Self-driving	262
Journal of Transportation Research Board	2005–2016	Public transport* network planning	3,216
Planning Practice and Research	All	Public transport network design	313
Transport Policy	2005–2016	Autonomous vehicle	26
Transport Policy	2005–2016	Mass transit reform	36
Transport Policy	2005–2016	Public transport network design	465
Transport Policy	2005–2016	Public transport system design	574
Transport Policy	2005–2016	Public transport system improvement	472
Transport Policy	2005–2016	Self-driving	221
Transport Reviews	To 2016	Public transport system design	636
Transportation Journal	1960–2016	Public transport network design	1,676
Urban Affairs Review	All	Public transport	39
Urban Geography	All	Public transport* network planning	58
Urban Policy and Research	All	Public transport network design	270
Urban Studies	2005–2016	"Public transport" network planning	262
World Transport Planning Practice	All	Public transport* network planning	41

Note: The asterisk (*) wildcard is used to yield results with "transport" and "transportation" terminologies.

though providers do have some incentive to connect to other transport infrastructure. Individual providers may swiftly meet new or changing demand patterns, leading to an organic state of service provision. However, unregulated service patterns caused by the confluence of several competing providers within a limited roadway can induce congestion, such as the bus bunching that can be observed in Hong Kong's or Edinburgh's urban core (Scheurer, Curtis, and Bell 2014). Electronic ticketing technology enables providers to offer interoperator transfer compatibility, but this requires a coordinating effort on behalf of a superior planning agency which is not necessarily in place or has the resources or authority to take such efforts. Very large operators with significant capital power, such as Tokyo's many privatized railway providers, have strong economic incentives to conduct their own development around transportation infrastructure investments (Cervero 1998; Chorus and Bertolini 2016). Otherwise and particularly in the case of bus systems, the interaction of these services with the urban fabric may be limited, as lines and stops often lack physical permanence (Mees 2000). Unless specifically legislated, operators may not enact disability access or universal user legibility standards. Operators and individual drivers may also operate recklessly, driven by profit motives (Pucher et al. 2005, 46).

The centrally planned model is characterized by permanent, fixed, legible systems, managed by a single organization or government entity, providing integrated fare systems and system programming. Depending on governance, this model may enable highly integrated long-term land use planning, where effective interagency governance structures exist-though in reality, this is far from universal, as transport and land use planning continue to follow processes with limited coordination in many cities (Imran and Matthews 2015, 57; Nielsen et al. 2005). While private enterprise is likely to respond to changing demand patterns, government planning may include consultation and public participation processes and allow contemplation of issues and strategies at the network scale (Pucher et al. 2005). Planning with reference to the other lines in the network can reduce overlaps, preserving operational resources. However, network changes may become politicized, and public investment in new routes or services may falter, particularly in neoliberal political climates. Politically driven piecemeal route deviation decisions may increase route circuity, resulting in poorer network speed (Walker 2008). Strategic regulation of providers can enable mitigation of common service problems, such as bus bunching, by reducing conflicting decisions and by implementing central control technologies (Pucher et al. 2005, 49). Ticketing is much more likely to be integrated, allowing for fare incentives such as free transfers or systemwide time discounting. Services provided by governments are likely to have mandatory disability standards, and legibility standards can be consistent across services, particularly to cater for marginalized users or tourists (Aarhaug and Elvebakk 2015).

Examples in the literature describe the formalization and consolidation of fragmented systems, particularly those in developing cities, into more cohesive, planned networks (Ferro and Behrens 2015; Jaramillo, Lizárraga, and Grindlay 2012; Pucher et al. 2005). Collaboration of small independent providers into cooperatives is an alternative reform strategy, though competitive forces can limit reform outcomes (Filho, Ribeiro, and Thiam 2015, 283). In some cases, formalization of previously fragmented demand-oriented systems into “modern” formalized networks may reduce mobility for some users, as the system becomes inherently less flexible and less able to rapidly meet changing demand patterns (Ferro and Behrens 2015). There is an inherent loss in flexibility and rapid adaptability of direct services, sacrificed in the trade-off for legibility and permanence. Some scholars argue, therefore, that providers must balance both network efficiency and social equity goals (Jaramillo, Lizárraga, and Grindlay 2012). This is not to say, either, that two diametric system typologies cannot complement each other; Ferro, Muñoz, and Behrens (2015) suggest that informal paratransit providers and small transport companies may compliment large formal networks by acting as feeder services. Indeed, Alpkokin et al. (2016) find that new light rail lines installed in medium Turkish cities were more successful when existing private bus system operators reoriented their services to feeder networks.

The prevailing view in the literature is that centrally managed systems are most desirable, as they allow for the strategic allocation of resources, and can be integrated in the land use planning process, thus stimulating land development investment (Nielsen et al. 2005, 81). In a broad review of public transit across thirty-three European cities, Fiorio, Florio, and Perucca (2013) found that single-provider systems are associated with higher levels of user satisfaction than free-market systems with multiple providers. Operational problems (such as roadway bottlenecks) can be better addressed, and route design can be focused on providing legible and consistently accessible services, even to those unfamiliar with the network (Pucher et al. 2005). Ideally, a single public sector agency should retain control of network design, ticketing, and branding, as those elements are central to high-quality outcomes (Mees and Dodson 2011). Governments may then still “privatize” operations by contracting the operation of services at the direction of that authority (Barter 2008; Pucher et al. 2005, 48). In these cases, or in public–private partnership projects, wise contract dictation, careful design of incentives, and effective ongoing contract management are pivotal to mitigating risk, optimizing operations, and ensuring good outcomes for users (Barter 2008; Gordon et al. 2013).

The importance of system simplicity cannot be understated as passenger turnover can be generally very high (Nielsen et al. 2005, 29). PT systems competing for mode share with the private car need to reduce barriers to access in order to maintain competitiveness (Woyciechowicz and Shliselberg 2005). Ease of use maximizes the scope of potential user groups and PT’s ability to serve tourists, for whom making inner-urban trips depends on a degree of user legibility. Ease of use of transit systems is closely correlated with satisfaction among tourists and incidental user groups (Thompson and Schofield 2007, 142). Good experience during incidental use is likely to encourage later use and potentially longer-term mode choice habits (Hung Wei and Yuan Kao 2010). Information technology may assist users to navigate an unfamiliar system, though evidence suggests that pretrip public transportation wayfinding systems may not themselves encourage PT use (Farag and Lyons 2012, 91). Hence, an easy-to-understand network is a pivotal foundation upon which a broader urban accessibility system is best built.

Network Design and Multimodality

While different ownership and governance approaches have seen diversity of PT delivery over time, it is possible to identify common PT network morphologies. These are described in this section together with a consideration of the purpose of PT lines and a discussion of the current best practice network type, including a discussion of new PT modes.

Network-oriented Planning

The radial, central city emphasis of traditional hub-and-spoke PT networks, oriented to service central city commuters, has been the subject of much criticism within the literature over a considerable period (Thompson 1977; Thompson and Matoff

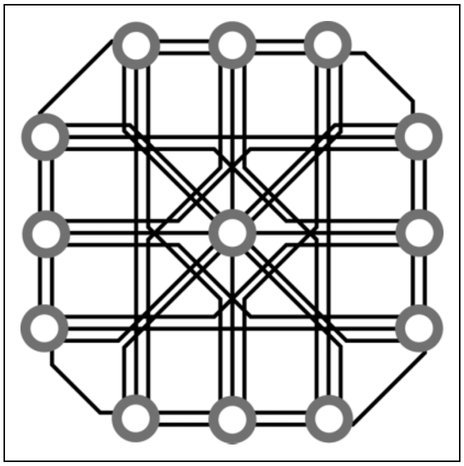

Figure 1. Ubiquitous network. Adapted from Thompson (1977, 160).

2003). Radial systems with lines that terminate in the city center instead of continuing through to an opposite line are particularly poor at delivering mobility, because no crosstown travel can be made without a centralized transfer (Mees 2000, 237; Nielsen et al. 2005, 120). Radial networks also centralize most transfers, even for orbital trips between suburban destinations. The decentralization and spatial diffusion of a large subset of employment and activity away from central cities during the second half of the twentieth century (Watkins 2014) to locations beyond PT access (based on the expectation that these places would be served instead by private car in the era of the "modern city") have left many traditional radial PT networks poorly equipped to service prevailing trip demand patterns. Network analysis with accessibility tools highlights the pressure placed on inner-urban links of radial networks, which make the network highly vulnerable to any disruption or sudden increase in patronage (Curtis and Scheurer 2016).

The prevailing commuter-oriented system design philosophy of the modernist era was informed and influenced, at least in part, by the well-documented reluctance commuters have toward transfers (Lawrie and Stone 2015). Three models exemplify such designs:

Ubiquitous/distributed. This is characteristic of Mees' (2000, 104) "Bangkok" model, where a service is likely to exist (or may be requested), albeit at very low frequency, or on a highly meandering route, indirectly servicing a litany of destinations. This model seeks to eliminate transfers (Figure 1).

Timed-transfer hub. Where coordinated "pulse" timetabling is used to allow passengers to switch between services at specific interchanges (Lawrie and Stone 2015, 2; Scheurer, Curtis, and Bell 2014; Thompson 1977). This model seeks to concentrate and limit interchanges (Figure 2).

Radial. Where all trips are to or through the urban core, at moderate frequencies, servicing central city commuter trips directly. This model reduces transfers for central business district commuters and centralizes all others at inner-city stations (Figure 3).

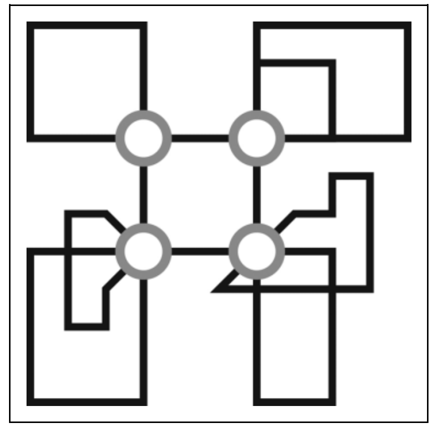

Figure 2. Timed-transfer network. Adapted from (Thompson 1977, 161).

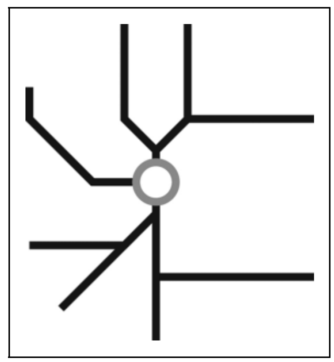

Figure 3. Radial network. Adapted from Thompson (1977, 160).

Network design planning embraces effective transfers, seeking to *improve* rather than *eliminate* them, thereby introducing a fourth model (Figure 4). Rather than emphasizing their impedance, Chowdhury and Ceder (2016) describe the function of transfers in increasing accessibility by expanding destination choices and reducing the duplication of parallel routes headed to different destinations, thereby saving operational resources. In this sense, perpendicular transfers are particularly advantageous—creating maximal accessibility benefits—while parallel transfers represent inefficient duplication of routes along a shared segment.

Grid/network. Where high-frequency direct services are available in a mesh-like structure, enabling rapid interchange at almost any intersection point (Mees 2000, 140; Nielsen et al. 2005, 86; Thompson 1977, 161). This model disperses transfers, using frequency and service directness to compensate for inconvenience.

The grid network morphology was initially conceived within a hypothetical grid-shaped urban structure (Thompson 1977), illustrated most pertinently in Mees' (2000, 139) famous

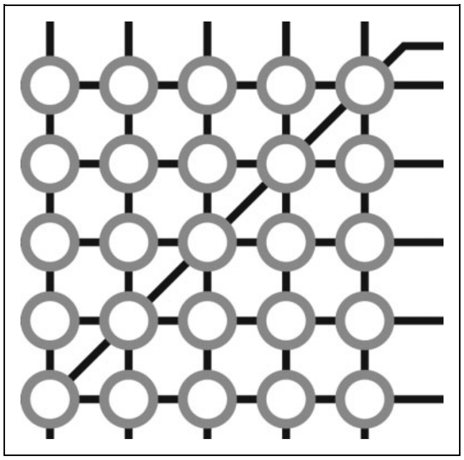

Figure 4. Grid network. Adapted from Thompson (1977, 161).

"Squaresville" thought experiment. Squaresville illustrates that a grid of services can deliver access between any two points with no more than a single transfer. In advocating for the grid/network typology, Mees (2000, 138) hypothesizes the "network effect," whereby such a large, multidestinational grid-like system, operating at adequate line frequencies, drastically increases mode share of PT by offering relatively direct access to a multitude of distributed locations. High frequencies ensure relatively quick transfers and can reduce the need for passengers to contemplate timetabling. Increased operating costs are offset by the overall increase of passenger fare-box revenue, through increased patronage (Imran and Matthews 2015, 64). Later refinements propose the layering of hierarchical route structures to further optimize the network model (Currie and Tivendale 2010; Dodson et al. 2011, 12). Central to the network model is the elimination of duplicate or competing routes, redistributing resources into either increased frequency along a consolidated single line or elsewhere in the system.

Within the constraints of available resources, network route planning has to balance competing goals. Walker (2008) characterizes the two main goals: *patronage* outcomes and *coverage* outcomes. Patronage goals tend to emphasize financial return, efficiency, or overall mode shift, whereas coverage goals place emphasis on providing geographic equity or meeting the needs of disadvantaged or reduced mobility groups. PT provision choices should be made with a clear appreciation for which goals should be given preference (Walker 2008; Nielsen et al. 2005, 19). Systems which have evolved across a long-term period of fragmented decision-making may lack any cohesive direction toward any particular strategic goal (Dodson et al. 2011, 16) and may exhibit duplication and waste which can be reallocated to improve overall service for no additional cost (Pucher et al. 2005, 46). Individual routes designed in an incremental, incoherent fashion are likely to be circuitous, lack directness, and fail to play a significant role within the network (Huang and Levinson 2015; Mees 2000, 239; Walker 2008). Put simply, the fundamental principle of network-oriented PT is that every route should effectively, efficiently, and directly service a specific flow of passengers, interlinked within the system to provide maximum transfer accessibility (Nielsen et al. 2005, 120).

Evidence continues to mount in support of the network typology. El-Hifnawi (2002) found that introduction of cross-town orbital routes over an existing radial system in Monterrey, Mexico, could result in significant mode shift and, therefore, ameliorate traffic congestion, reduce travel costs, and curtail externalities. While square-shaped topologies are typically used to illustrate grid networks, more recent research suggests that fractal triangular network structures may be an improvement, depending on local geography (Bell 2015).

Networked systems are optimistically considered a means by which car dominance and petroleum price vulnerability might be ameliorated (Stone and Mees 2010). Increasing PT mode share has various well-documented (Hickman, Ashiru, and Banister 2010) social, economic, and environmental benefits, particularly as rail-based PT modes are broadly much cheaper to construct and operate than the same capacity in private motor cars (Glazebrook 2009). The network effect's tantalizing promise of competitive journey times between a wide range of destinations has seen it adopted as best practice, adopted in the influential *HiTrans* guide to PT network design (Nielsen et al. 2005, 84; Dodson et al. 2011). Nielsen's guide has informed several network redesigns internationally (Imran and Matthews 2015; Mees et al. 2010).

Multimodality in Urban Transit Networks

Effective PT systems must employ several transit modes to perform different accessibility roles within the network (Krygsman, Dijst, and Arentze 2004; Vuchic 2007). Different modes have different accessibility attributes and are thus each suited to performing specific mobility roles of individual lines within a network. Strategic hierarchical and multimodal distribution of PT route investment is essential to achieving economically efficient operations (Currie and Tivendale 2010). In a review of thirty-four PT projects in the United States, Zhang (2009) calculated the cost of light rail infrastructure as 2.64 times more than bus rapid transit (BRT), and metro rail around 12.82 times more expensive than BRT, per distance unit. Modeling supports the economic feasibility of successive upgrades to mode types along routes, as the catchments undergo urban succession and maturation. Xu and Lin (2016) find that successive upgrades to routes—from BRT to light rail to metro—is a cost-effective approach to urban development in dense Chinese cities.

Recent literature further emphasizes the varied application of on-road PT modes depending on service context. Particularly in sprawling cities, bus routes should be designed to serve a specific mobility purpose within a broader hierarchical network (Devney 2014), rather than deploying buses in a heterogeneous mesh of local services.

The introduction of new or improved PT services can promote significant mode shift. Mode shift may generally be much higher in fringe areas, where existing service provision and network access is low (Ho and Mulley 2014). Evidence from Paris suggests that investments to improve the speed of bus links in the outer suburbs yield significantly higher network benefits than increasing the speed or capacity of metro lines near the center of the city (Bureau and Glachant 2011), further emphasizing the promise of nonradial network effects. This also supports the notion that network-oriented systems require fewer expensive inner-city infrastructure investments than heavily radial systems. The degree to which a system attracts "low involvement" discretionary patrons (who make casual or poorly informed decisions of mode choice) determines the viability of the system (Hung Wei and Yuan Kao 2010); therefore, expanding high-frequency lines across a city is likely to initially capture some latent demand and gradually encourage residents to form habits centered on transit.

Embracing and Managing Transfers

Inherently, "grid" or "network" PT systems necessitate transfers at a dispersed range of intersecting nodes throughout the city. While transfers are recognized as inconvenient and undesirable, almost all PT trips will involve some form of change between modes. Short transfer times are universally critical to encouraging users to accept multimodal PT trips. Stated preference surveys conducted on Dutch train commuters by Schakenbos et al. (2016) found that eight minutes is an optimal acceptable transfer time, though preferences vary substantially between demographic groups, travel purpose types, and geography. Other survey data from Santander, northern Spain (a regional area of 250,000 inhabitants), strongly support PT waiting time as the most significant metric influencing user mode choice (dell'Olio, Ibeas, and Cecin 2011). Lawrie and Stone (2015) suggest that, for car-centric, low-density, suburban-oriented postwar cities (such as those commonly found in the United States and Australia), between four and ten minutes is an optimal transfer time period. They suggest that reluctance to transfer is influenced by previous experience of low-quality transfers. Thompson's (1977, 162) grid model was based around frequencies of less than ten minutes. Research in New Zealand (Chowdhury, Ceder, and Schwalger 2015) found that users were willing to make transfers provided that overall journey time was shortened, and preferably where transfer locations offered a high level of physical comfort.

Recurrent in the literature is the need to contemplate trips door-to-door (Aarhaug and Elvebakk 2015), with appropriate interventions to the design of the public realm. It is well established that personal safety fears are an influential factor in discouraging PT use (Currie and Delbosc 2013; Delbosc and Currie 2012). Increasing the degree to which older people or limited-mobility persons believe they are capable of accessing transport networks is an important element in encouraging sustainable mobility usage (Ryan, Wretstrand, and Schmidt 2015). The quality and amenity of interchange facilities are significant to improving journeys for passengers, especially in larger, sprawling cities, where trips are more likely to necessitate transfers (Hernandez and Monzon 2016). However, urban design is no panacea or substitute for a high-quality network. Iseki and Taylor (2010) found that passengers would prefer a shorter wait for a better service in a low-quality environment, rather than a longer wait for a less regular service in a high-amenity environment. They conclude: "In sum, we found that transit users tend to care more about personal safety and frequent, reliable service than the physical conditions of transit stops and stations" (Iseki and Taylor 2010, 24). While time spent transferring is generally undesirable, time spent while riding PT services may have some utility for commuters (Ettema et al. 2012). Interviews of young commuters in the UK suggest that an emerging competitive attribute of PT is that passengers may derive some usefulness from their travel time, particularly with the increasing ubiquitousness of portable computing and social media (Line, Jain, and Lyons 2011).

New Technology and Complementary Nontraditional PT

Informal services and on-demand modes have a long history of complementing formal systems by acting as feeder services (Ferro, Muñoz, and Behrens 2015; Alpkokin et al. 2016). However, the potential impacts of new and innovative transportation services and modes on traditional PT networks remain unclear. New transportation technologies range from publicly owned (such as subsidized bike share systems), new private enterprise services (taxi-like ride sharing), new private products (electric and autonomous cars), and contemporary forms of co-ownership, like car sharing. These modes respond to demand in novel ways and have been characterized as post-Fordist distributed systems (Glover 2014). The potential effects of ride sharing on PT patronage are unclear. Some evidence suggests that on-demand ride services may replace a proportion of PT trips (Rayle et al. 2016), while there is also the potential for ride sharing to feed passengers onto traditional PT systems. Despite the anticipated promulgation of self-driving cars and a diversified market of on-demand transport services, rail transport may be likely to retain speed and price competitive advantages between key urban centers, owing to the mode's inherent speed and efficiency (Glazebrook 2009).

While traditional PT may have to compete with new modes, it may itself adapt through the application of improved management technology. Nelson and Phonphitakchai (2012) describe the application of "demand-responsive transport" (DRT), responsive and flexible prebooked bus services, in being especially effective in servicing very local trips for concessionary users. Forms of DRT, such as "dial-a-bus" services, have existed in various forms for several decades, though increasingly ubiquitous communication technologies are improving services by significantly optimizing operations. Liu and Ceder (2015) describe the popularization of "customized" bus services in thirty cities across China, illustrating the competitiveness of the mode against the private car, particular in dense, congested cities. Li and Quadrifoglio (2010), in contrast, point to the rapidly mounting operating costs of DRT services, in comparison to the greater economies of scale achievable with fixed-route transit, in conditions of higher passenger demand. Bike-sharing schemes may increase the catchment of traditional fixed PT lines, especially in low-density areas,

Table 3. Potential Future Public Transport Network Multimodality.

Core, High Capacity Network	Interchange Extension: Publicly Managed Investments	Interchange Extension: Private Investments
Grade-separated heavy rail	Demand-responsive transit routes	Taxis, on-demand chauffer services, ridesharing, car sharing
Light rail	Bike share	Autonomous (self-driving), electric cars
Bus rapid transit	Pedestrian realm improvements, cycle networks	
Strategic/ targeted local bus routes		

or at city fringes (Jäppinen, Toivonen, and Salonen 2013; Martin and Shaheen 2014). Autonomous cars or ride-sharing services could also be considered a form of demand-responsive transportation (Milakis, Van Arem, and Van Wee 2015). Application of DRT for specific user groups or mobility purposes is therefore a possible mechanism for mitigating against the reduced spatial coverage of consolidated patronage-oriented network systems that Walker (2008) describes. In this sense, DRT could form an additional layer to formal PT systems, absorbing much of the sporadic demand that previously meandering low-frequency buses inefficiently served. The provision of such modes integrated with traditional PT systems is a tantalizing prospect for the future of sustainable mobility. One potential extended urban passenger PT network is detailed in Table 3.

Integrating PT with Land Use Planning

Increasingly, multimodal passenger transport in cities is likely to see greater spatial proliferation of transfers. The likely nature of resulting transfer development matches the postmodern spatial planning structures that have been increasingly popularized and applied to improve transport sustainability across metropolitan regions since the 1990s (Curtis and Olaru 2010, 53). Planning at the neighborhood level, encouraging self-containment (i.e. people working close to home rather than undertaking long commute journeys), and transit-oriented development (TOD) are foundational concepts that fit within a framework of designing places within a polycentric network of neighborhood transfer points. The distribution of new local transfer points poses immense opportunity for new urban center developments at new route intersections, while multimodal networked PT systems also pose new opportunities to increase the effectiveness of existing stations and TODs. The implementation of networked systems may trigger a new phase of polycentric, networked cities, with a patchwork of mixed-use, increasingly self-contained precincts (Curtis 2006).

The role of TOD is multifaceted, and the functions of an effective TOD are inextricably interlinked. Effective TOD can have multiple benefits. It will introduce mixed land uses and improved "place" qualities through station infrastructure and public realm investments (Bertolini's [1999] place in his node–place concept). It can also act as an exemplar and catalyst for denser development locally and concentrate residential catchments around interchange points (Mees 2014; Vale 2015). A review of twenty-seven BRT projects in various international cities by Cervero and Dai (2014) identified that cost minimization in infrastructure provision results in suboptimal urban development outcomes around stations, illustrating the relationship between service provision and reciprocal private land investment. TOD can improve the multimodal transfer potential of the existing network, often triggering a reconfiguration of nearby transit services (Martinoivich 2008; Mees 2014, 462; Scheurer, Curtis, and Bell 2014, 7).

TOD can drive private land investment creating the potential for value capture, where uplifts in property prices attributable new transit infrastructures are harvested through taxation instruments or public or private development initiatives that contribute to the cost of infrastructure investment (McIntosh et al. 2017). On the other hand, others have found that value uplift and consequent redevelopment created by improved transit services may threaten affordable housing and the social equity associated with it (Jones and Ley 2016, 19; Moore 2015). Rezoning initiatives triggered by the infrastructure installation may further exacerbate the process of gentrification. Rayle (2015), however, highlights that there is little empirical evidence of displacement of lower-income residents at TODs, contending that the effects may be subtle, highly complex, or difficult to measure. Nonetheless, any housing affordability externalities caused by transport investments can be alleviated through affordability requirements for new buildings (Dawkins and Moeckel 2016). Clearly, planners must grapple with the challenge of ensuring any land value benefits that arise from improved PT infrastructure are distributed equitably.

TOD further enables residential self-selection, whereby people most likely to utilize PT decide to reside proximate to stations (Mokhtarian and Cao 2008). It can improve the polycentricism and multidestinationality of the city's PT system (Cats, Wang, and Zhao 2015) and "lock-in" long-term transit level of service by both fixing infrastructure investment and creating a population reliant users who will oppose service cuts (Newman n.d.).

The original and simple concept of TOD has been subject to considerable advances in planning literature since Calthorpe's (1993) and Bernick and Cervero's (1997) early influential works. Bertolini's (1999) node–place model provides an excellent nexus for the evaluation and balancing of the mobility and land use functions of a station precinct. However, subsequent research has emphasized the need to evaluate a broader diversity of TOD typologies (Cats, Wang, and Zhao 2015; Kamruzzaman et al. 2014). Vale (2015) expands on the node–place model by incorporating pedestrian network analysis to further differentiate between pedestrian-oriented residential "dormitory" TODs and more transfer-oriented multimodal TODs. Even simple analytics such as drawing walkable catchments around interchanges have been widely used to evaluate the success (or potential) of urban development planning around stations (Allan 2014; Curtis 2005). Australian evidence shows that introduction of TODs tends to increase the modal diversity of local commuters (Kamruzzaman et al. 2014). Olaru and Curtis (2015) illustrate that patronage gains can be maximized regardless of station type by improving walking and cycling adjacent to the interchange.

The potential for individual TODs as a "silver bullet" approach to retrofitting low-density car-centric regions is relatively limited in comparison to the potential for multimodal feeder systems to expand the reach of the system more broadly (Curtis 2012b; Martinoivich 2008; Mees 2014; Mees and Dodson 2011, 17). Even in high-patronage heavy rail TOD precincts in already dense cities, the percentage of train passengers who walk directly to railway services is relatively low, compared to those who arrive by feeder bus services (Mees 2014, 467). In contrast, both Lawrie and Stone (2015) and Mees (2014, 468) find that the majority of passengers embarking on to Melbourne's radial commuter rail network are walking to stations from nearby residential properties and suggest that patronage gains could be attained through improved multimodality in a more networked, transfer-oriented structure. Following Bertolini's node–place model, Mees (2014) describes historical examples of TODs as either:

- prioritizing local urban design amenity (for TODs designed for maximum residential concentration), often neglecting multimodal transfer potential—Bertolini's "unbalanced place"
- or prioritizing multimodal transfer potential (such as rail or bus interchanges or the classic "Park and Ride" station type)—Bertolini's "unbalanced node."

Advocates of rail's competitive advantage over highways have supported the development of park and ride stations, particularly in car-oriented cities (Martinoivich 2008). Park and ride railway stations, often separated from the surrounding urban fabric, are the dichotomous opposite of urban TODs, comprising few nearby residences and little urban amenity (Mees 2014, 465). Examples of railway stations in low-density suburbia in Perth, Australia, attract up to two-thirds of railway passengers from feeder bus services, with most of the remainder arriving by private car (Mees and Dodson 2011, 17). However, TODs realize their full potential to discourage car travel when they function as both a destination and an exchange point, rather than a dormitory or surface car park along a single line. Cats, Wang, and Zhao (2015) compared Stockholm's station precincts by commuter flow data, finding that only a small subset of station precincts attract inward PT passengers through active land uses. They attribute this failure to transition to a more multimodal network as stalling the realization of mixed-use polycentrism. Chorus and Bertolini (2016), in contrast, investigate rail movement and land use development patterns in the larger and (concerning mixed-use polycentrism) more successful agglomeration of Tokyo. They highlight the importance of dedicated strategies and synergistic collaboration of public and private actors to diversify and intensify land use in a string of subcenters along a rail corridor in order to optimize the performance of the rail service and the land use system alike. Hence, TODs should exhibit a degree of interconnectivity to at least two PT axes, enabling transfers, and destination land uses. This notion reflects the rationale behind the earlier Dutch national spatial policy, which aimed to develop settlement intensification and transport networks in a mutually supportive process, thus understanding both the urban–regional geography and its transport infrastructures as components of an integrated network (Bertolini and Le Clerq 2003; Bertolini 2005; Van der Bijl and Hendriks 2010).

Commercial centers at and adjacent to mixed-use TODs will attract trips from adjacent areas beyond the core railway corridor. In instances where little networked connectivity and interchange potential exists, those trips are likely to be made by car, increasing the need for parking, resulting in a suburban-style urban environment, and diminishing the effectiveness of TOD (Mees 2014, 463; Vale 2015). Thus, there is a risk that poorly designed TODs will merely replicate car-oriented suburban centers or act as car-dependent highway interchange proxies.

The influence of new PT system investment on land use is mixed and not well understood (particularly where regulatory control is weak). Further, it is useful to acknowledge these tensions in the challenge of measuring system performance. PT system planning and design outcomes may be measured only in terms of the direct outcome of transit ridership, or they may also be evaluated with reference to the more indirect benefits of land use change, and the complex interactions between transit, communities, economic activity, and the environment. Historical analysis in New York suggested that the subway acted as a long-term agent of economic decentralization (King 2011). More effective land use planning adjacent to stations along new rail projects in Europe amplifies their regenerative effects (Mejia-Dorantes and Lucas 2014, 251). However, Chatman and Noland (2011) note that there remains limited evidence to support the hypothesis that PT improvements induce economic agglomerations, suggesting that city form and local factors are likely to be overwhelmingly influential. This is congruent with Curtis and Mellor (2011), who found that for firms located close to a new commuter railway, their location decisions do not appear to be influenced by opportunities created by the railway. Some authors have also stressed the importance of developing communities of regular users along PT routes not only to ensure continued ridership but to create a political bloc to withstand budget cuts or negative service changes (Newman n.d.). The increased value of properties resulting from the transit infrastructure (McIntosh et al. 2017) should also be a force to further consolidate local support for the line (Rodríguez and Mojica 2009). We contend, therefore, that the lasting permanence of urban development approaches, in conjunction with high-frequency rail or high-quality fixed BRT systems, will build immunity to reductions in the level of service, particularly compared to low-quality meandering bus routes of radial or ubiquitous network types, further contributing to user certainty, legibility, and the realization of network effects.

Activity corridors have also been promoted as a form of linear TOD model, suitable for implementation in the "greyfields" along existing arterial roads (Curtis and Tiwari 2008; Jones, Marshall, and Boujenko 2008). Activity corridors are likely to become increasingly common, owing to the comparative affordability of on-road modes (Zhang 2009). They may also be an effective tool in transitioning car-reliant park and ride stations to multimodal TODs, by creating substantial linear catchment corridors, feeding the station with transit passengers. Activity corridors also mirror emerging international trends for strategic roadway planning, such as the removal of grade-separated urban highways and the conversion of arterial roadways to more multimodal boulevards in Stockholm and Helsinki (City Planning Department of Helsinki 2013). The importance of direct, rapid, and networked PT lines should also be a relevant subject for consideration in street network design and structure planning processes, particularly where surface modes are likely to pass through.

The land use density required to feasibly support relatively high-frequency PT services without excessive subsidies has been the subject of considerable conjecture (Curtis 2012a; Mees 2000, 146). Such debates, though often highly context dependent, are likely to partially discount the less quantifiable benefits of transit, and Mees's (2000) hypothesized network effect. In any event, these different examples serve to remind us that designing future PT systems must account for the complexity of relationships with land use and planning and with multimodal transport systems. The future is shaping up to be increasingly multimodal, with a broader diversity of modes and transfer types. To remain effective and efficient, we assert that PT systems must not be planned in "silos" where land use planning may be "blinkered" but instead must be planned as part of increasingly sophisticated urban systems.

Implementation

The most ambitious goal of any PT system is to compete with the private car (Nielsen et al. 2005, 24), and thus, cities must decide the degree to which PT will competitively address passenger mobility demand. Many cities implicitly make this decision through the allocation of institutional power and associated infrastructure prioritization, albeit tempered by the effect of path dependencies (Curtis and Low 2012; Vigar 2002). From the above, it is evident that PT has limited scope to attract discretionary users if it cannot offer frequent services, convenient transfers, and access to a broad range of destinations comparable or close to the car. These immense tasks are much less feasible without adequate investment.

Comprehensive network redesign, coupled with increased investment, poses the greatest potential for improving sustainable urban mobility options. Small local improvements, such as individual bus lanes, are unlikely to yield substantial ridership benefits to the broader network in isolation (Bureau and Glachant 2011; Pucher et al. 2005, 47). However, improving line speeds by signal priority, rationalizing stops, providing segregated rights-of-way, and reducing delays caused by ticketing and boarding reduce operational costs by reducing the number of vehicles required to deliver the desired line frequency (Martinoivich 2008, 17; Hensher 2007, 101). These dividends can then be reinvested to further gain network effects, by extending lines further into fringe areas, where there may be greater latent patronage to be absorbed (Ho and Mulley 2014). Additionally, if speed and reliability can be managed, increasing the length of lines (while maintaining directness) further improves accessibility because the scope of destinations that can be reached on that line without a transfer increases (Nielsen et al. 2005, 120). Other innovative operational optimizations, such as the strategic placement of standby bus fleets, can be employed to improve individual network performance characteristics, such as resistance to stoppages or debilitating events (Pender et al. 2014).

Considerable research has been undertaken to maximize the operating efficiency of public transportation (Vuchic 2007). Many researchers have suggested the optimization of networks through the application of highly sophisticated mathematical network models (Guihaire and Hao 2008). Big data created through the emergence of electronic ticketing can be used to inform evidence-based network design (Tao et al. 2014). Data mining techniques can also provide insights into transportation networks in near real time (Gal-Tzur et al. 2014). While these sophisticated mathematical models and computational optimization tools are useful, qualitative, experiential, and consultative methods are also critical to designing both transit systems and the urban fabric around them (Napper, Coxon, and Allen 2007; Walker 2008). High-level strategic transportation issues cannot be solved through only engineering approaches, since the sophisticated multidimensionality of urban transport cannot be compartmentalized into individual solvable parts (Cascetta et al. 2015). Qualitative research is also important in assessing transport access equity, since factors which inhibit travel (such as perceived safety, timetable legibility, or obstacles in the pedestrian realm) may not be evident in census data or GIS analysis (Blair, Hine, and Bukhari 2013, 194). For example, service delays caused by passengers with luggage may be entirely imperceptible in computational optimization modeling, remaining overlooked without observational or communicative investigations (Napper, Coxon, and Allen 2007, 5).

Blockers and Enablers of Network Reform

Despite the promise of networked systems, reform programs do not follow a universal trajectory and have highly variable outcomes. Marsden and Stead (2011) assert that implementation of good integrated transport policy, not the absence of it, is the key problem. Cascetta et al. (2015, 28) describe transportation planning problems as inherently "wicked," suggesting that the poorest outcomes in transport planning decision-making tend to, at least in part, occur when rational decision-making, stakeholder analysis, and technical analysis are not balanced or well integrated. Curiously, there are innumerable cases of transportation project failures in the literature (Cascetta et al.

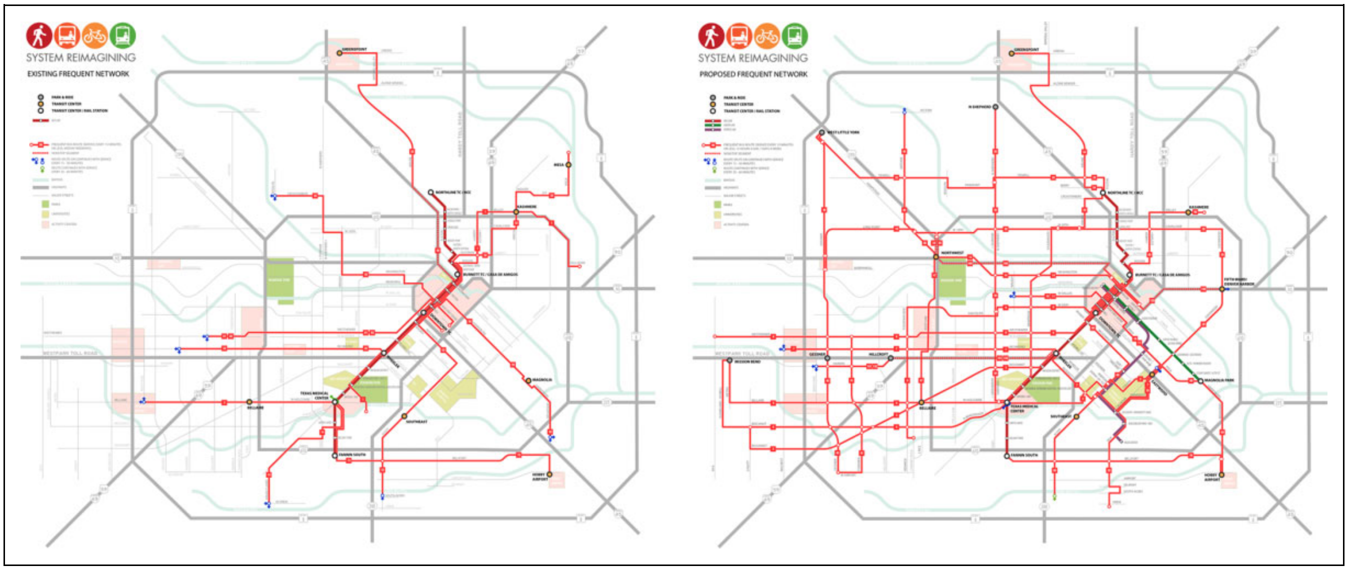

Figure 5. Houston's high-frequency bus network before (left) and after (right) reform.
Source: Bliss (2016).

2015), but sources on what constitutes "worst" or "poor" *practice* are very limited (Macmillen and Stead 2014, 85).

Broadly speaking, deliberative, integrated governance is associated with far more sustainable and effective transport and land use integration outcomes (Hrelja 2015; Mejia-Dorantes and Lucas 2014). Policy transfer and heuristic learning occur between adjacent transport planning jurisdictions (Marsden et al. 2011; Marsden and Stead 2011), suggesting that successful projects may trigger similar endeavors in nearby cities. Evidence suggests that the success of new transportation lines depends upon the degree of complementary land use planning and the integration with other transport services within the urban mobility system (Alpkokin et al. 2016; Mejia-Dorantes and Lucas 2014). Collaboration between agencies to develop agreed strategic plans is essential to the realization of the benefits of integrated transportation and land use development (Mejia-Dorantes and Lucas 2014, 251). Interagency coordination between governing agencies and transit providers is pivotal to the realization of good outcomes (Sørensen and Longva 2011). Congruent with the centralization theme identified in the literature, Mees and Dodson (2011, 4) assert that best practice PT governance should ideally be undertaken by a regional authority, allowing for both spatial and institutional congruency. Further to these thematic findings, analysis of the case studies cited in the following paragraphs provides insight into the pathways that result in rapid, successful trajectories or the languishing abandonment of genuine reform.

Following development of a best practice report for the New Zealand government, extrapolating Nielsen's network planning principles (Mees et al. 2010), Auckland has gradually embraced PT reform. Imran and Matthews (2015, 57) credit legislation to regulate and centralize management of services with enabling this broad system reform. Auckland previously exhibited the typical characteristics of a distributed and radially oriented network of meandering bus routes, lacking coherent planning, and providing meagre competition to the private car (Imran and Matthews 2015, 63). While considerable progress has been made in restructuring services in subregional areas, Imran and Matthews (2015, 64) blame a strategic emphasis on constructing additional park and ride capacity to the system, and poorly conceived incentives for private service operators (which encourage slow, meandering routes), for distracting and impeding efforts for greater network reform. Emphasis on increased car parking at stations, rather than embracing multimodal TODs, seems reminiscent of depreciated and obsolete local-level, network-agnostic transportation planning, and might even impede the long-term realization of network effects.

Large, single events can crystallize significant and cohesive integrated interagency planning. The 2000 Sydney Olympics prompted a concerted and coordinated effort to provide integrated event transport, to considerable success and acclaim (Mulley and Moutou 2015). Sadly, though, the innovative practices were abandoned at the close of the games because fragmented "business as usual" governance resumed (Mulley and Moutou 2015). The Sydney case hints at the pathology of failed reform, where daily performance mediocrity is simply accepted as standard practice.

A highly successful transformative system reform in Seoul, driven by very poor bus network performance, saw implementation through the consolidation of fragmented private operators, operating at the direction of a public authority, with improved incentive structures. This included the hierarchical, color-coded design of four route types, depending on service purpose, aimed at producing a legible system; improved multimodal transfer points at metro stations; GPS-based dynamic fleet management, allowing for rapid resolution of operational problems by reallocation or rerouting of vehicles; unification of fare, and ticketing systems, thereby speeding up boardings and reducing transfer impedance; and pedestrian realm improvements to bus transit corridors (Pucher et al. 2005). Both user satisfaction and average bus speed immediately and significantly improved. Support and collaboration between political and technical change advocates were central to the realization of the ambitious reform program (Pucher et al. 2005, 48).

Houston has recently undertaken a bus network reform project, heavily influenced by Walker's (2008) principles. By redistributing existing resources more efficiently, a much larger high-frequency network has been introduced, creating additional transfer nodes and broadening accessibility beyond a central radial core (Figure 5). While empirical evidence for the reformed system has yet to be published, this project does highlight the potential accessibility improvement opportunities posed by previously inefficient networks.

Facilitation is critical where network overhauls might reduce local access to slow services, even in exchange for slightly less local access to a much more efficient metropolitan network (Imran and Matthews 2015, 65). Walker (2008, 436) describes the role of stakeholder engagement in raising stakeholder awareness of the inherent trade-offs that must be made when designing a network. Early engagement with local communities is also critical in reducing the impact of "NIMBYism" on project delivery (Cervero and Dai 2014) and to encouraging more effective, nuanced dialogue between decision makers, planners, and the general public.

The potential for substantial improvement at minimal extra cost incentivizes network reviews or redesigns. Timetabling restructuring has been used extensively as a strategy to minimize transfer inconvenience (Balcombe et al. 2004, 76). Interestingly, Currie and Tivendale (2010) found reviews of PT networks in Australia have been undertaken more frequently than generally assumed, but technical, bureaucratic, and stakeholder constraints can limit their effective implementation. Stakeholder engagement can overcome many of these blocks and vastly improve the outcomes of review (Currie and Tivendale 2010). Implementation of best practice principles to bus services in suburban Melbourne has shown improved patronage for limited investments in extra services, by emphasizing route hierarchy, maximizing route directness, careful use of service resources, and synchronization between buses and commuter rail (Loader, Langdon, and Robotis 2015). Generally, restructuring bus networks to feed rail infrastructure has proved cost-effective in Australian cities, with the potential for 10 percent to 30 percent increases in patronage (Currie and Wallis 2008). These projects demonstrate the advantages of utilizing transfers between modes to improve urban mobility.

Conclusions

Effective PT networks are legible, coordinated and frequent, and utilize transfers to service a diverse range of trips across urban areas. Formal PT networks should be multidestinational, providing access across cities along rapid, direct lines, especially for orbital trips. Lines which travel to the city center should continue through, and, where possible, most lines should extend to the city periphery, particularly where line speed can be maintained.

Demand-responsive modes of transportation (such as bike sharing, ride sharing, autonomous cars, and demand-responsive buses) can broaden the catchment of formal PT systems, and service sporadic travel demand patterns which cannot be efficiently met with traditional bus or train services. This potential for demand-responsive modes to make up the "first mile" or "last mile" of trips, and to service sporadic late-night trip demand, may enable formal transit providers to reorient their service resources to providing very efficient, frequent networks. Interestingly, the concurrent recent expansion of informal transportation options in highly developed cities, and the coordination of some previously fragmented lines into more formalized networks in developing cities, may be indicative of the emergence of a common passenger transport system typology in cities globally. We infer that almost all cities might be tending toward a typical archetype, where formal rail and BRT do the heavy lifting of moving large flows of people, in a high-frequency, multidestinational network, while the informal and on-demand sector compliments the system, expanding catchments in low-density areas, and servicing obscure trips at obscure times which PT cannot efficiently serve.

We conclude that transfers and the interplay of multiple modes must play an increasing role in informing land use and urban design policy, especially proximate to new transfer nodes. Implementation of such transformative PT futures requires a regionally oriented approach, interagency collaboration, and should exploit the symbiotic benefits of PT and urban development to achieve the best possible outcomes. In all, the findings of this systematic review support the paradigm of PT-oriented urban mobility and provide an optimistic insight into the future of sustainable travel in cities.

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