Integrated Urban Transport and Distributed Systems for Urban Mobility: A Convergence of Ideas in Sustainable Transport?

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Abstract

Sustainable transport is concerned with the provision of mobility for people and goods with low negative environmental and social impacts. Over several decades a number of approaches, concepts, and tools have been developed to assist decision-makers in the public and private sectors in promoting sustainable transport. Integrated urban transport is a concept with a broad interpretation. It can refer to different scales and phenomena, including the integration of services within modes, integration between different modes, and the integration of land use and transport planning. Successful integration can reduce the environmental and social costs of transport, such as by promoting increased public transport use, allowing seamless public transport journeys, reducing travel demand, and improving per capita vehicle energy efficiency. Distributed system concepts have been taken up in several industrial sectors in response to the limitations of highly centralised approaches, notably in electricity generation and supply systems, water and wastewater infrastructure, and in coordinated computer networks. Several recent proposals for sustainable transport appear to evoke distributed systems concepts, such as the promotion of diverse travel choices, on-demand public transport, public bicycles, and lift-sharing services. This paper aims to consider whether integrated urban transport concepts and distributed systems for urban mobility are complementary, overlapping, or contradictory ideas. Outputs of this paper could contribute to the broader debate over sustainable transport.

1. Introduction

This paper aims to examine two popular concepts—integrated urban transport (IUT) and distributed systems (DS) and consider their relevance to the goals of sustainable transport. Neither of these concepts has a single and widely accepted definition, but in the simplest terms an IUT refers to integrated transport services within a location and DS refers to a decentralized system connected through a network.[1, 2] These concepts are examined in light of their contribution to sustainable passenger transport in Australia, which is interpreted here broadly as mobility with low environmental and social costs and on which there is now a voluminous literature. A number of commentators on sustainable transport have identified the importance of effective governance for achieving sustainable transport (e.g., ECMT 2002, Kennedy et al 2005, Low 2011, Reitveld and Stough 2004, and Szyliowicz 2003) and this paper studies the contribution of both concepts to sustainable transport. In the next two sections, the IUT and DS

[1] Integrated urban transport: Definition is discussed further below in Section 3.
[2] Distributed systems: Definition is discussed further below in Section 4.

concepts are examined in turn, then in the following section an analysis is made of the relationship between the two; the paper finishes with a discussion and conclusions.

There are at least two reasons for considering this issue. Firstly, if these are separate concepts, then there are opportunities to see how each might contribute to sustainable transport research, public policy development, and policy implementation. Secondly, if these concepts differ, then there are opportunities for mutual critical examinations and insights into each, from which conceptual refinement and improvement can be based. If it is found that these concepts are identical, then it can be argued that the use of each is interchangeable and need not be debated further.

In this paper, these concepts are put into a broader context of the developments recognized in a number of overlapping fields of inquiry, including transport policy, urban studies, institutional studies, public policy, and the governance of large systems. Although our focus here is transport policy and its related fields, we are interested in a number of broader trends in politics, technology, economics, and culture that have shaped the circumstances in which transport policy and planning is formulated, applied, monitored, and assessed. Understanding this context is important for several reasons. These questions involve institutions, which can make an essential difference in achieving sustainable transport—either positively or negatively (Reitveld and Stough 2004). Both the IUT and the DS concepts mark an evolutionary change to the established model of transport systems, as explained below. This change was not the outcome of internal dynamic processes within the world's transport systems, but the consequence of external factors that subsequently produced a range of outcomes in different locations and over time. If we are to understand the character of IUT and DS, then we need an appreciation of the forces that gave rise to these concepts.

As a useful starting point, it has become common in recent decades in the social sciences to identify the rise of a network society, as Castells (2000) put it, and the associated decline of central and hierarchical authorities (such as governments), with authority, resources, and communication becoming more widely dispersed and shared by other policy actors. While there is controversy over whether state authority has become fragmented and decentralized, there is little dispute that this period has been one of considerable change for public policy and planning for cities, urban systems, and urban passenger transport. Regulation and management of urban infrastructure systems, including transport, has been profoundly altered in Australia and in other nations. Guy et al (1997) describe this process as a splintering of the 'delivery, development and management' of these urban networks which, in turn, produces a fracturing of the institutions involved and produces social inequities. Others consider the processes as progressive outcomes that are economically and socially desirable (e.g., World Bank 1996).

By way of introducing these concepts, both mark departures from the mode of production that dominated the economies of the developed nations from the beginning of the era of mass production and mass consumption until late in the 20th century, often referred to as 'Fordism'.[3] Industrial organization in this period was marked by economies of scale favouring large outputs, domination by large firms, vertical integration, mass production, mass consumption of standard products, and hierarchical control (Capello and Gillespie 1993). Through this century, households in the developed nations became increasingly connected to large infrastructure systems for water supply, wastewater, transport, gas and electricity, telephones and television,

[3] Fordism: Defined by Graham and Marvin (2001: 425) as: "The interconnected social, technological, cultural and political construction through which mass production, distribution and consumption societies were elaborated in Western countries between the 1920s and 1970s."

car access, so that towards the end of the 20th century, almost all urban households were a part of these systems of infrastructure-delivered services. Interestingly, in the case of urban mobility, there was a change of course in the 20th century, with the infrastructure for motor vehicles supplanting that for urban passenger rail in most places, with the ideal form of personal mobility being the private motor car.

While progress to the ideal of these extensive and uniform infrastructure systems was being realized, a number of economic, social, technological, and cultural trends were developing and would lead to alternative approaches to the 'modern infrastructure ideal'. These trends included globalization, market liberalization, and technological change. This change also generally coincided with the end of the 'long boom' of post-war economic growth. Graham and Marvin (2001) identify several infrastructure crises that came to challenge the infrastructure ideal since the late 1960s. Firstly, there was the infrastructure crisis of deteriorating urban infrastructures and the prohibitive costs of maintaining and/or replacing these assets. Secondly, the changing political economies of urban infrastructure was marked by privatization of infrastructure services, often as a result of fiscal crises facing state owners in developed (and developing) nations. Thirdly, there was a collapse of comprehensive urban planning and its replacement with a concentration on projects rather than comprehensive and strategic plans and attempts to address local problems rather than "utopian or visionary frameworks for re-engineering metropolitan regions according to idealized blueprints or desired urban forms" (p. 103). Fourthly, there was the physical growth of metropolitan regions. Fifthly and finally, there was been the challenge of social movements and critiques. Obviously, this last category is potentially quite large, covering such changes as the rise of environmentalism, neo-liberalism, and globalization.

Given that these infrastructure systems were either owned or controlled by governments, these crises had implications for the state and its relationships with the corporate and community sectors. Urban transport was a part of these changes; the governance, ownership, institutional design, and public policies governing today's transport systems in the developed world (and in much of the developing world) are greatly changed from those of a generation ago. Sager and Ravlum (2004) found that transport planning was shaped according to its institutional circumstances and examined the different influences of systems characterized by hierarchy, market, and networks. Across different fields of scholarship and perspectives we find different interpretations of this phenomenon of global change, and while these views are highly varied, they are clearly responses to this change (whether as a single multifarious change or set of linked and co-incident changes).

2. Transport system configuration and sustainable transport

In this short section on a complex subject, some of the major associations being made by sustainable transport advocates between the configuration of urban passenger transport systems and sustainable transport goals are identified. Put simply, it is held by these advocates that a substantial portion of the high environmental and social costs of models of urban mobility based on private motor vehicles can be reduced through a transition to greatly reduced private vehicle use and increased use of public and active transport. A major factor in this transition is integration in transport systems (Birk and Zegras 1993, EC 2003a, Newman and Kenworthy 1999, Szyliowicz 2003, and Westerman 1998a, b). Public transport systems are a major focus for integration strategies, as it has been empirically demonstrated that the number of trips, number of linked trips, and levels of mode share increase with the level of integration, such as facilitated by coordinated services, unified timetables, interchange facilities, and unified fare and ticket systems (CIT 2001a, b). Many sustainable transport advocates promote the integration of land use planning and transport planning to create urban designs and plans that reduce travel

distances, reduce journey numbers, and increase public and active transport usage rates. Social benefits from greater public transport integration include greater mobility welfare and net social benefits by increasing overall services (such as increasing the area serviced, frequency of services, and journey speeds) that disproportionally benefits those dependent on public transport. Some advocates have sought to add new services and 'greener' modes to existing systems. A key aspect of this case is the rejection of increasing urban mobility through increasing road capacity in favour of investing in more diversified modes, including public transport.

3. Integrated urban transport

Integration has become a dominant theme in contemporary transport policy and been widely taken up in scholarship, public policy formulation, transport and land use advocacy, and professional education and training. One difficulty with the IUT concept is that its successful recognition in a range of applications now undermines its clarity, as reflected in the array of definitions and understandings of IUT. This prompted Janic and Reggiani (2001: 470): "So far there is no generally accepted definition of the term 'integrated transport systems'. This is, however, the term commonly used for systems providing door-to-door passenger transport services." Despite the absence of a single definition, the concept is in widespread use and it is possible to examine these different interpretations. Beginning with a simple scaled approach, IUT can refer to integration of components within an operational sub-system in the transport system, such as the coordination of public transport services, integrated public transport ticketing, and the like. At the next scale, IUT can refer to integration between transport systems, such as might occur in transport planning, so that public and private transport systems are considered as complementary parts of an urban transport system. Above this scale is land use and transport integration, as exemplified by transit-oriented development.[4]

Potter and Skinner (2000: 281) acknowledge this view and also offer a catagorisation based on scale and function in a nested typology:

> "Points on this scale from lower to higher are:
> - Functional or Modal Integration, which is part of….
> - Transport and Planning Integration, which is part of….
> - Social Integration, which is part of….
> - Environmental, Economic and Transport Policy Integration".

IUT can, therefore, refer to one or all of these levels or types of integration. Exemplifying a more comprehensive perspective, the European Commission (EC 2003b), identified three elements of integrated transport: 1) Policy and institutions; 2) Management and operations; and 3) Planning, design, and implementation. For their purposes, the Commission recognized a series of 'levels' to be considered in integrated transport: Socio-economic environment, Mobility policy, Public transport, Interchange and surrounding areas, and Interchange infrastructure. May et al (2006) thought integration occurred in four ways: 1) Between policy instruments involving different modes; 2) Between policy instruments involving infrastructure provision, management, information and pricing; 3) Between land use planning and transport planning; and 4) Between transport and other policy areas. This approach broadly matched that of Glover (2007) who found that integrated transport systems assume their particular characteristics in each city due

[4] Land use and transport integration (LUTI) is understood in many different ways, but a common interpretation is that transport planning and land use planning is an integrated activity producing a singular planning output that optimizes the goals of both disciplines relative to each other; Transit-Oriented-Development exemplifies LUTI.

to the influence of transport governance (i.e., institutions, organisations, and policies); the guiding rationale for the transport system (i.e., values, principles, and goals); characteristics of the transport system (infrastructure and services); and urban form and function.

Most attention is given to operational aspects of IUT, especially as these apply to public transport, reflecting Janic and Reggiani's (2001) aforementioned observation. An example of this approach is Viegas (1999) who identified three dimensions of integrated transport:

- Physical: As occurs in space and time (e.g., interchange stations and coordinated timetables);
- Logical: System information shared by operators and managers; and
- Tariff: Packages of transport services using integrated prices.

Integrated transport is one of the goals of the European Commission; its 2003 teaching materials on integrated transport described it as (EC 2003b: 60): "… the extent to which different transport services are combined or contiguous in terms of ownership, operation or usability". A 2004 European Commission report (EC 2004) noted that integrated transport necessitated both a planning principle and a journey type so that passenger intermodality facilitates combined trip chains across different modes in a seamless journey.

Network planning, an approach based on integration of public transport services, is a specific example of IUT (Neilson et al 2005, Dodson et al 2011). Network planning is a principle in transport planning based on conceptualising transport systems as networks—as opposed to routes or individual modes. Dodson et al (2011: 3) refer to public transport network planning as "… the intensive coordination of public transport services to achieve the 'network effect' and not in a general or broad sense of just offering some undefined level of public transport service." Such a network effect is achieved when the system provides for "seamless multi-destination travel" that generates high patronage levels by serving many passenger types and a wide range of demands (Dodson et al 2011: 2). These authors draw a distinction between a network and a system; the former describes infrastructure, technology, and information, whilst the latter, "describes the spatial and temporal relationship between the lines of connection provided by the system" (Dodson et al 2011: 4). Several guides have been produced for network planning, such as the European Commission's HiTrans project (Neilson et al 2005). Reviews of Australian (Mees and Dodson 2011) and New Zealand practices are available (Mees et al 2010).

From an institutional perspective, integration is often taken to imply restructuring multiple agencies into single units. Arranging public transport services to improve performance within a single agency or administrative unit can reap the benefits of coordination. Governance of transport sectors is, however, usually a complex matter involving many agencies and stakeholders, often leading to efforts at coordination rather than integration. In reviewing Australian land use and transport integration, Westerman noted (Westerman 1998a: 15): "There are mechanisms for co-ordination and these are widely used. Integration, however, goes much further. It involves common objectives and specific programs (including funding) designed to achieve them. Co-ordination alone does not achieve this." Integration is therefore an objective that entails consideration of institutional design and practices.

Although it is common enough to find the different components of public transport within a single public agency for a city or state, it is equally common to find a highly disaggregated model. Within the Australian context, planning for transport and land use are invariably state government functions handled by different jurisdictions. Co-location of functions does not necessarily imply an integrated approach, the obvious example of which has been the treatment of the roads and public transport portfolios in Australian governments and the rarity of coordinated planning between the two, despite widespread co-location within state transport

agencies and reporting to a single government authority. Such alignments between theme and dedicated bureaucracy/ agency typically have considerable historical inertia that persists through numerous public sector reorganizations.[5] Observing this phenomenon in the US federal system in transport mode-based institutions, Szyliowicz (2000: 309—310) stated:

> Because of this history, each mode possesses its own organizations, cultures, constituencies and powerful interests who benefit from a modal focus. Congress and its committee also reflect modal interests and are responsive to these groups. State/local units are also linked to modal interests. Hence, while there are powerful forces supporting each mode, there are few politically effective intermodal groups and the balance of power remains heavily biased in favour of the specific modes, especially highways. Furthermore, particular modal cultures are deeply embedded in most organizations, including state Departments of Transportation.

There have been efforts to create transport with structures designed to facilitate IUT; Germany's *Verkehrsverbund* approach of coordinating urban public transport is widely recognized as a model of best practice (e.g., Mees 2000, Pucher and Kirth 1996). Originally developed in Hamburg in the late 1960s in response to create a single institution to oversee and coordinate both public and private service providers, the verkehrsverbund was designed to address uncoordinated timetables, high fares, disjointed and uncoordinated services and modes, difficult and inconvenient transfers, and slow services (Pucher and Kurth 1996). Dunn (1980) noted that rising financial losses to governments from public transport deficits (who carried the bulk of passengers) also prompted governments to act. Three states, 140 cities and towns, and seven public transport firms formed the *Hamburger Verkehrsverbund* (HVV) in 1967 to coordinate public transport services, leaving service delivery to the transport corporations (Pucher and Kurth 1996). Central HVV functions include public transport planning, service delivery levels and timetabling, network route design, fare structures and prices, distribution of fare revenues to member firms, and public transport marketing, advertising, and public relations. It is worth noting that, however, this model does not extend to land use planning functions. Private operators provide the transport service and make decisions on staffing, maintenance, and vehicle choice. Now widespread in Europe, this institutional model is used in Berlin, Frankfurt, Hanover, Munich, the Rhein-Ruhr region, Stuttgart, Vienna, and Zurich (Pucher and Kurth 1996). Recently, the state of Victoria created Public Transport Victoria with the express purpose of more strongly integrating the different public transport service providers in order to give effect to earlier state legislation seeking IUT goals.

4. Distributed systems for urban mobility

DS are applied in a number of fields, notably computer science, infrastructure design, logistics, and systems engineering, but in this paper we are concerned with the applications to urban systems and to passenger transport, in particular. As the antithesis of centralised systems, DS are usually depicted as comprising a number of autonomous units that are linked and/or coordinated so as to function as a single unit. A more elaborate depiction of DS refers to infrastructures to facilitate production, distribution, and consumption within specific locations and/or communities to as to match demands and local natural resources/ ecological services. Urban applications of DS concepts have concentrated on energy and water systems and we turn to the literature on these developments to learn how the DS concept has been developed

[5] One study of the influence of path dependency in the state institutions governing Melbourne's transport system found that the public transport agencies had undergone considerably more reform than had those dealing with roads (see Low and Astle 2009).

and applied. Urban infrastructure systems, as described in the Introduction above, came in maturity to be characterised by their large scale (partially because many constituted natural monopolies) and high capital intensity, thereby entailing long investment and payback periods. As such, these systems exhibited interdependency between the system components and their owners sought efficiencies through economies of scale and standardisation of technologies, components, management, and operations. For managing these large systems, institutions based on centralisation and hierarchy were favoured.[6]

Electricity systems developed, in the most part, under state control using a small number of large generators and an extensive transmission grid; as cities grew, increasing demand for electricity was satisfied by adding further large generating units (either thermal, nuclear, or hydropower stations) and extending the grid's capacity and geographical reach.[7] Towards the latter 20th century this model was revised; government ownership was subject to corporatisation and privatization, monopolies were broken up, generation came from a variety of differently scaled sources, renewable energy became more widespread, and many small consumers generated their own power and contributed to the grid. Meeting rising demands for electricity by increasing capacity came at proportionally increasing costs and utilities turned to demand-side management, increased energy efficiency programs, and used generation from smaller-scaled units. Many of these changes cumulatively altered the existing model of electricity systems under centralization to one increasingly known as 'distributed generation'.[8]

Ackermann et al (2001) reviewed the definition of distributed generation in the energy sector and found many different applications by different authorities and differing approaches to the definition, including definitions based on purpose, location, energy rating, power delivery area, technology type, environmental impacts, operating mode, ownership type, and extent of market penetration. Energy systems have undergone several revisions in recent decades and the DS concept reflects several of these changes, hence the different perspectives on the concept. These changes include the entry of new technologies for generation (notably renewable energy), far smaller generation units, energy generation at the point of consumption, new generation in areas not previously serviced by the existing electricity grids, use of new generating sources in specific applications, and new models of ownership and investment. Generally, the authors found that distributed generation meant generation within the network and/or generation 'on the customer side' of the network.

Similarly, water and wastewater (and stormwater) systems have undergone a shift away from highly centralised models for harvesting, treatment, collecting, and distribution to decentralised approaches under various headings, such as integrated water resources management and sustainable water cycle management. DS for water supply feature producing, treating, collecting, and distributing water through a network of local water schemes that include household, neighbourhood, and suburban scales. For the energy and water utilities, DS has emerged as a new orthodoxy, marked by the emergence of NGOs and government programs promoting their use. For example, in the US, the Dept. of Energy has a major distributed energy program; the EU has the European Distributed Energy Partnership, and internationally, there is the World Alliance of Decentralised Energy. Central to DS in these systems is the change in

[6] Not surprisingly, large urban infrastructure systems were the subject of many early management science studies.

[7] An 'energy system' encompasses energy production/ generation/ conversion, distribution/ transmission, and consumption.

[8] Also called dispersed generation, embedded generation, decentralised generation, and on-site generation (Ackerman et al 2001, Alanne and Saari 2006).

governance, as marked by these new programs and institutions, giving rise to a number of new governance issues. Alanne and Saari (2006), for instance, identify the role of decentralization in creating distributed systems: “Generally, the question is about transferring functions from an upper hierarchy level to a lower one”, thereby entailing a redistribution of authority and resources.

DS are a revolutionary change in urban infrastructure systems and their governance. Many of the aforementioned Fordist model features that were once taken for granted no longer applied and the thinking about governing large systems was transformed (e.g., Coutard 1999). Examples of some of these changes are shown in Table 1 below.

Table 1. Features of Large Urban Infrastructure Systems: Fordism and Distributed System Models.

Fordism	Distributed Systems
Large scale	Local scale
Capital intensive	Smaller investments, lower risks, shorter payback periods
Vertical integration strategies	Outsourcing and contract supplier strategies
Efficiency goals	Efficacy/ consumer satisfaction goals
Centralised (and hierarchical) management models	Decentralised and multiple management
Monopoly supplier	Multiple ownership
State owned and/or controlled	State, private, and community ownership
Standardised services	Customised services
Economies of scale	Niche markets

Sources: After Guy et al (1997), Harvey (1989), and Stough and Reitveld (1997).

Several aspects favour DS over centralised system designs, such as the ability to more closely match infrastructure and service delivery with local circumstances. From the perspective of environmental values, DS can align demands with local resource availability (as resource harvesting or using environmental services) and waste assimilation capacity than large, centralised systems. With distributed points of production and/or consumption, DS have greater flexibility (and security) of supply than centralised systems and offer greater resilience in the face of disruptions or abrupt changes in demand characteristics. DS can entail increased costs over centralised systems, but these may be offset through reducing the costs of transport/ transmission arising from efficiency gains of more closely located points of activity and the opportunities of co-locating production and consumption. Greater overall system efficiency is also possible by mixing production units of differing scales to achieve optimisation goals.

Such advantages can yield environmental and social benefits. Improved environmental performances have become a prerequisite for urban infrastructure systems, some of which can be produced by technological improvements and increased efficiency in resource use and waste production. Additional to the aforementioned benefits to service providers are those increased opportunities for households to engage in production and adopt more personalised consumption, offering greater autonomy and opportunities to exert control over household expenditure. Correspondingly, there are greater opportunities to develop community-based

enterprises, social enterprises, small corporations, and in developing other necessary institutions, and all of which entail concomitant opportunities for innovation.

As stated above, DS has not been commonly applied to thinking about urban passenger transport systems, despite its widespread use in transport logistics. It is possible, however, to identify a number of passenger transport activities that fit the DS concept. Exemplars of DS in urban passenger transport comprise a highly varied set of activities. Community transport, which is largely provided by local governments in Australia (albeit, with considerable federal funding), is effectively separate from routine passenger services and characterises the de-centralised aspect of DS. Services such as lift-sharing, such as offered by some employers to employees, private car sharing promoted by governments, or new services—such as coordinated taxi-sharing services, are also a form of DS for transport. On-demand services, as offered for those with special mobility needs (e.g., the disabled or elderly), are also a DS within the larger transport system. Bicycle share schemes that have become popular in recent years, as in Brisbane and Melbourne, provide an active transport form of DS. Other examples might be extended to services for individual travellers that entail behaviour change or information services, such as campaigns to promote more diverse travel choices and schemes for personalised travel plans (e.g., Perth's *TravelSmart*[9] and the Gold Coast Council's *Travelsmart*[10]).

Associated with these DS activities are specific institutions, stakeholders, and policies that may or may not be a part of traditional transport systems. Community transport services, for example, are largely administered by local governments and federal and state welfare and health agencies. Features of DS (as exemplified in Table 1 above) are found in the state and city agencies dealing with public transport. Even within the established public transport providers there are changes suggestive of DS. An obvious change to the agencies managing public transport operations is the shift away from vertical integration and into outsourcing, of which the state rail services are a good example. At the height of their operations, both city and regional rail operators were engaged in building rolling stock, building infrastructure, operating services, providing maintenance, managing railway stations and associated services, undertaking public relations and marketing, and so on. By many measures, these enterprises were of great importance in the national economy and society; they were large public enterprises, employing many, and commanding large capital works programs of nation-building scale. Today, this picture is quite different, with most of these functions handled in different ways, such as through privatisation, corporatisation, and outsourcing and contracting. Associated with these changes are shifts away from state monopoly ownership to private and other ownership models. These examples demonstrate that there are many different institutions involved in providing mobility services and that these services, in many cases, are largely unconnected from urban public transport services (to the extent that some commentators express concern that these services undermine public transport).

5. Discussion

Much of the importance of large urban infrastructure-based services can be said to be hidden in plain sight; the economic and social benefits enjoyed by the majority of urban dwellers are in a large part due to the supply of energy, water, wastewater services, and mobility. Indeed, these services are often used as indicators of social and economic progress. In developed nations, such as Australia, these services usually only draw wider attention when supply is temporarily

[9] See: http://www.transport.wa.gov.au/activetransport/24605.asp
[10] See: http://www.travelsmartsunshinecoast.com.au/

disrupted or services are subject to price hikes. Policy-makers and scholars, however, have been considering a range of issues facing these services in recent decades, amounting to a revolutionary change, as described above, and in this paper we are focusing on the demands of sustainable transport.

From the perspective of the urban passenger systems, the demands of sustainable transport can be said to give rise to two distinct types of problems for managing these systems:

- *Fragmentation* of the major components of the transport system that has arisen from long-standing and historical reasons, and the realization that other portfolios (that have traditionally been largely independent) need to be coordinated with transport; and
- *Formation* of new types and forms mobility services typically servicing niche demands and markets that are weakly connected or disconnected from the established transport systems.

These problems have an institutional dimension and the responsibilities for their resolution largely fall within the domains of the state-based transport (and related) agencies; in short, these problems invoke questions of governing large public infrastructure-based services. We can examine each problem in turn. Firstly, there has been a governance effort to address the problem of transport system fragmentation through integration strategies of various kinds, based on the view that transport systems ought to constitute a whole. For example, Dodson et al offer a version of the urban public transport passenger mobility problem (2011: 5):

> The overriding challenge for public transport planners in any given city is to deploy a finite system of spatially fixed lines and nodes to satisfy the near infinite demands of the residents of that city, within the prevailing institutional and operational restraints on finance and management.

This leads to governance solutions designed for unified transport systems. Improving governance institutions for integration requires re-working of the centralizing authorities managing these systems in order to satisfy new agendas and circumstances. Consequently, either new central institutions or existing institutional arrangements are modified to take up the functions that would formerly have been within the domain of a central authority. Essentially, this centralization (or *re-centralisation*) of transport governance is necessary because of the new forms of integration required within the sector, such as breaking down the mode-based 'silos' in managing public transport (as exemplified by the aforementioned *verkehrsverbund* model). In many ways, integrating land use and transport planning is but another version of the same problem and one that brings forward similar kinds of institutional solutions.

Yet greater integration of existing functions and services is not a complete answer to the problem of sustainable transport. To begin, there are mobility needs that cannot be met within urban transport systems, regardless of the extent of integration of existing services. Existing systems can be modified and expanded, but innovation in large, centralized systems is typically slow. For these needs, ways must be found to provide for additional mobility services that will occur 'outside' the limits of the existing system. A centralized and integrated system implies a small range of institutional choices and ways of operating, making it difficult and expensive to accommodate new models of ownership and management. Technology changes are also more difficult to exploit in centralized systems, as is innovation more generally. Overall efficiency is always difficult to gauge and comparisons between different institutional models are often an artifact of the choice of performance indicators, however, highly integrated systems have to contend with the need to accommodate multiple stakeholders and competing interests.

In examining urban passenger transport we find that there are a number of stakeholders and mobility services that are not a part of the centralized system, which has led to the aforementioned second response, namely that of the formation of new types and forms mobility services. Urban passenger transport does not, therefore, always confirm to the rationale that it comprises a single system—but rather is a system comprised of a combination of sub-systems, some which are integrated and under central management together with sub-systems that are not completely integrated or centrally managed. An apparent contradiction arises from this condition, namely that, on one hand, there are urban passenger systems in which there is a need for greater integration and this prompts the call for centrally management. On the other hand, there are aspects that are not part of this integration (such as the service gaps, mobility needs, and mobility opportunities not met by the major service providers) and these do not fit under the model of centralized management.

There is insufficient space for a comprehensive account of the factors behind these changes (including the effects of neo-liberalism, new technologies, globalization, cultural change, and the demands of the sustainable development), as outlined above. Briefly, three effects on IUT and DS are examined.

Firstly, there are changes relating to *internal dynamics*. These factors include the level of public financial support for public transport, technological development and innovation, and the rise of 'co-production'. For IUT, for example, this has resulted in increasing capacities to monitor and program overall operations and facilitating integrated ticketing systems. New communication technologies have provided options for off-site working to reducing commuting that is arguably an exemplar of a DS. Co-production is of interest as it implies the creation of new types of mobility demand and novel ways in which these demands might be satisfied. Both IUT and DS approaches to transport are potential strategies to increase the resilience of urban transport by offering more strongly connected networks, increasing system operating choices, reducing dependence on private motor cars, creating more personal mobility choices, and other factors (e.g., Newman et al 2008).

Secondly, there are *external politico-institutional changes*, of which, the influence of neo-liberalism has been particularly important in how it affects firms, governments, and the relations between them. Efforts to scale back the public sector transport agencies, expose more state transport activity to market signals, and allow the entry of firms into transport operations produced many changes with implications for IUT and DS for transport. In many respects, neo-liberalism complicated the task of integration as in the absence of market signals favouring integration, initiatives like corporatization and privatization tend to foster competition between service providers rather than cooperation. Initiatives to form IUT systems have been based on new state-supported institutions with powers to enforce cooperation between entities. Regulated competitive regimes can prevent integrated solutions, such as the Thatcher government's abolition of the UK's regional transport bodies (see, e.g., Knowles (1998) on the UK rail privatization). DS, in contrast, can be promoted by neo-liberal approaches, because of the mutual interest in weakening of the monopoly supply and vertical integration strategies of the mode-based public transport agencies.

Thirdly and finally, there are *environmental sustainability objectives*. Taking the environmental agenda in a broad sense so as to include the issue of natural resource restraints, there are a set of critical issues that impinging on current and future urban mobility. From the perspective of IUT to the problems of pollution (including greenhouse gas emissions), can be added the problems of peak oil and security of fossil fuel energy supply in many nations, including Australia. Such issues are prompting governments to deploy IUT to promote greater land use

and transport planning, more use of public transport, and investment in cleaner energy sources and motor vehicles. These same influences produce different issues from a DS perspective and evoke an external evaluation of the transport system. An example is the questioning of the institutional benefits of encouraging consumption growth and recognition of the benefits of consumption conservation and dealing with the challenges of mobility demand management (e.g., Metz 2008). Utilities providing services will need to look increasingly for other opportunities to reduce their environmental costs beyond the confines of their immediate operations. Including access and equity to mobility into sustainable transport draws attention to current inequities, an issue that becomes more apparent if transport systems are assessed on the effectiveness of their networks. Recognising that the market for passenger transport is highly segmented over time and distance prompts the need for response strategies (Hine and Grieco 2003, Currie et al, 2007). Without explicit measures to address these market failures, continued market liberalization will only increase the extent of inequity in mobility access. A response under IUT is likely to focus on extending the existing networks, whilst the DS response might seek solutions such as a community transport and specialized services. Evidence of both responses can be found in Australia's cities and regional centres, although much of this latter effort has been supported by agencies with a social welfare mission rather than being led by transport agencies.

6. Conclusions

This paper sought to determine whether IUT and DS, in the context of sustainable transport, were concepts that described the same idea, different ideas, or were related in some other way. In summary, it is proposed that these are different concepts describing different ideas, but that both are central to the quest for sustainable urban passenger transport.

Identifying aspects of IUT and DS in transport infrastructure is unsurprising as these are features of contemporary urban infrastructure systems networks in Australian for many major services, including electricity, water and wastewater, and telecommunications. These systems have undergone significant change from monopolistic public ownership to complex mixes of public and private providers over the last generation; in comparison, the extent of change in public transport has not been as extensive, but nonetheless has been significantly reformed.

IUT and DS can play a role in sustainable transport. IUT has become an established approach to promote sustainable transport supported by a considerable body of research and public policy in Australia, worldwide, and from international agencies. Although the concept is applied to many phenomena and different scales, it remains a valuable policy approach to reducing environmental and social costs of the transport sector. DS is not currently a transport policy concept but is commonplace in other urban and rural infrastructure fields and in computing and communications networks. It appears that DS is applicable to a number of transport initiatives and programs and that transport systems may resemble DS.

IUT and DS have arisen from a common set of external influences on the transport system that highlight two different sorts of problem. IUT is a response to the problems within transport systems by building effective internal relationships within extant transport systems or across to other systems to address mutual issues. DS is a response to problems outside the existing system by efforts to accommodate or incorporate solutions into the extant transport system that necessarily expands the system. External influences on transport policy regime are producing, therefore, problems that challenge the effectiveness of the centralized models of the transport system and problems that characterize a decentralised or multi-centered transport system.

As integration of transport proceeds, the system becomes more inclusive in its coverage, more extensive in its relations with other portfolios, more centralized in management, and more unified to common visions and goals. An outcome of this interconnecting process is paradoxical as it makes existing gaps in the existing system more apparent; the greater the effort to bring mobility under the auspices of a single rationale brings alternatives rationales forward. These concepts may be linked in the following way: the more an IUT develops, the greater the claims for DS and conversely, the greater the diversity and disaggregation within a transport system, the greater the rationale for integration. Future scholarship could further address the problem of the applicability of the DS concept to transport policy and planning to promote sustainable transport.

Acknowledgements
Insightful comments and helpful advice from the reviewer are acknowledged with thanks.

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