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Sustainable urban transport: Four innovative directions

Todd Goldman [a,*], Roger Gorham [b]

[a] CUNY Institute for Urban Systems, MR-910, City College of New York, New York, NY 10031, USA
[b] U.S. Environmental Protection Agency, 1200 Pennsylvania. Ave. NW 6406J, Washington, DC 20460, USA

Abstract

This paper examines the concept and implementation of sustainable transport. It traces efforts to define and operationalize the notion of sustainable transport in the urban context, noting that these efforts have tended to fall into two broad clusters of work: those that envision sustainable transportation as a policy pathway, and those that envision it as a policy end-point. The authors argue that to be successful, sustainable transport policy must avoid the common transportation policy pitfall of ignoring the larger systems in which transportation activity is embedded. The goal of sustainable transportation may be better served by a number of the organic innovations in transportation practice that are occurring in the field. The authors identify four emerging areas of innovation: New Mobility, City Logistics, Intelligent System Management, and Livability. Finally, the authors discuss the extent to which these innovations represent a more systems-oriented approach, and the institutional challenges inherent in these proposals.
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1. Introduction

Since the 1987 Brundtland Commission report [1] brought global attention to the concept of sustainable development, scholars and policy professionals have worked to apply its principles in the urban and metropolitan context. Sustainable development has proven an enduring and compelling concept because it points policy in a clear, intuitive direction, yet is flexible enough to adapt to emerging new issues, technological and economic conditions, and social aspirations. It is appealing to advocates and scholars alike because it implies a systemic view of economy and ecology, and requires comprehensive solutions that protect the interests of future generations. It is a testament to the power and utility of this concept that after nearly two

* Corresponding author. Tel.: +1 212 650 8071; fax: +1 212 650 8374.
E-mail address: goldman@utrc2.org (T. Goldman).

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decades, efforts to translate it into the mechanisms of urban[1] policy continue to flourish, despite tremendous political, economic, social, institutional, and technological challenges.

Yet, the transportation sector has proven to be particularly difficult territory for the advancement of sustainable development policy. Transportation is a complex and porous social, technical, and economic system, difficult to address comprehensively. To the extent that policy guidance has been developed to address sustainability issues in general, it usually has only touched on a fraction of the myriad ways that transportation is integrated into larger systems of human activity. Meanwhile, current trends are not encouraging. The most transportation-efficient cities in the world are facing escalating motorization and mobility demands. Travel is increasing in virtually all regions of the world, usually at or faster than the rate of economic growth, and generally faster in the long run than the rate of reduction of energy and pollution intensity. In Europe, known for its historically compact urban centers, suburbanization and regional economic integration are powering the same growth in intercity goods movement and passenger transport observed elsewhere. In the megacities of East Asia, a surging middle class is pouring its new wealth into automobiles, while governments are pushing bicycles off the streets and expanding roadways at breakneck pace. If these cities, with historically efficient urban structures, are facing such setbacks, then the prospects for other cities look dim.

This paper examines some policy disconnects impeding the advancement of sustainable urban transport policy, and identifies some promising ideas for how they may be repaired. We argue that taking into account the human activity systems in which transportation occurs—for example, systems of human settlement and economic production—are crucial if efforts to advance 'sustainable transport' are going to be successful. Section 2 traces the development of the term 'sustainable transport' and efforts to create policy guidance to help with its implementation. Section 3 examines four innovative directions in the real-world implementation of sustainable transport policy—New Mobility, City Logistics, Intelligent System Management, and Livability. Section 4 concludes by discussing some cross-cutting lessons.

2. The meaning of 'sustainable transport'

As articulated by the Brundtland Commission, sustainable development meets the needs of the present without sacrificing the ability of future generations to do the same. These 'needs' are now widely accepted to include goals related to economic development, social and human development, and environmental and ecological health. In the context of natural resource policy, sustainability would mean limiting depletion of resources to the rate at which they can be replenished, or alternatives can be identified.

In the transportation sector, however, exactly which resources are of concern when the term 'sustainable' is used is always in question; different groups may have different resources in mind. To be sure, the transportation sector does consume depletable resources: energy, human and ecological habitats, atmospheric carbon loading capacity, and individuals' available time. But solutions that reduce depletion of one of these may exacerbate depletion of another. Moreover, transportation decisions tend to be made in the service of larger policy goals: economic growth and job creation, the character and intensity of land use, and socioeconomic and geographic transfers of wealth. These powerful but often unstated agendas mean that

[1] This paper uses 'urban' and 'cities' inclusively to describe entire metropolitan regions.

approaching sustainable transport simply as an exercise in resource optimization is somewhat naïve.

In the decade since a conference organized by the Organization for Economic Cooperation and Development in 1996 first grappled with the question, there have been ongoing efforts to develop and operationalize the notion of 'sustainable transport' into useful policy guidance. These projects have taken varied directions, but tend to fall into two broad categories: those that envision sustainable transport as a pathway, and those that envision it as an end-state.

2.1. Sustainability policy as a pathway

One cluster of efforts avoids attempting to define a particular outcome that would mark the 'attainment' of sustainability. These efforts instead suggest policies to push society along a path that is 'more sustainable' than present trajectories, as measured by a set of indicators.

One example this definition-by-directionality approach was the European Conference of Ministers of Transport's (ECMT) 'Sustainable Urban Travel' (SUT) program (1997–2001). This initiative did not define sustainable transport *per se*, but nonetheless sponsored a series of workshops aimed at addressing "why implementation of integrated sustainable policies has proven to be so difficult." [2].

The World Business Council for Sustainable Development's (WBCST) 'Sustainable Mobility' program also refrains from providing a definition or specific policy vision. This initiative proposed a framework of 11 different sets of indicators, measuring progress toward a set of seven 'goals' to 'improve the outlook' sustainable mobility [3]. It essentially defines 'sustainable mobility' as the direction implied by adopting policies that presumably improve these indicators.

Initiatives that focus on directional indicators such as the ECMT/SUT or the WBCST Sustainable Mobility project have the advantage of being relatively easily understood by policy makers and the general public, and, in principle, easily conceptualized as specific policy initiatives. However, because they fail to grapple with the complexities and contradictions of sustainable transport and the larger social and economic systems in which transport is embedded, they are prone to tautologies and circularities that either overlook 'unintended' (and potentially unsustainable) consequences, or overstate what can be realistically expected from particular policies.

The WBCSD Sustainable Mobility project, for example, generally ignores the accessibility and productive systems in which transportation sits, and from which it derives its economic value. Instead, it focuses on one component—'mobility'—and gives it primacy over other possible components of a transportation/accessibility/productivity system. Accessibility as a concept is virtually ignored in the outcome, except in its distorted meaning of 'access to mobility'. The result is that whole areas of sustainability policy—those that try to reduce mobility—are off-limits, 'blind' to the very system that the project sponsors have defined. The resulting tautology may not, in the larger picture, be particularly sustainable.

2.2. Sustainability as an end-state vision

Other efforts to operationalize the concept of sustainable transport have endeavored to come up with a definition or vision of what a sustainable system might look like. These projects often rely on indicators as well, although these are used in service of the vision, rather than as a replacement for it.

Following its 1996 conference, the OECD undertook a longer-term project focusing on 'Environmentally Sustainable Transport' (EST). This project developed a definition of sustainable transport as one where transport "does not endanger public health or ecosystems and meets needs for access consistent with (a) use of renewable resources below their rates of regeneration, and (b) use of non-renewable resources below the rates of development of renewable substitutes" [4]. This definition goes on to specify that for a transportation system to be considered sustainable, the following criteria must be met: health standards for nitrogen oxides, ozone, particulates, and noise; international objectives for transportation sector emissions of carbon dioxide; and ecosystem protection objectives relating to land protection in urban areas.

The Council of Transport Ministers of the European Union adopted a more expansive definition of sustainable transport in April of 2001. This approach, an adaptation of an earlier proposal by the Centre for Sustainable Transport (CST) in Toronto, sees sustainable transport as a system that:

- "Allows the basic access and development needs of individuals, companies and societies to be met safely and in a manner consistent with human and ecosystem health, and promises equity within and between successive generations
- Is affordable, operates fairly and efficiently, offers choice of transport mode, and supports a competitive economy, as well as balanced regional development
- Limits emissions and waste within the planet's ability to absorb them, uses renewable resources at or below their rates of generation, and, uses non-renewable resources at or below the rates of development of renewable substitutes while minimizing the impact on land and the generation of noise." [5]

Both of these approaches emphasize a vision of some kind of desired end-state, yet they differ from each other in an important way. The OECD/EST vision—perhaps because it limits itself explicitly to the *environmental* component of sustainability—provides a vision of the system's *constraints*, not one of the system itself. The vision statement emphasizes what sustainable transport should *not* do: endanger public health or eco-systems. The EU/CST approach, on the other hand, begins with a positive and concise statement about what the ideal system *should* do, namely allow for basic accessibility needs.

Both approaches can be faulted for failing to provide a meaningful way of approaching the problem that is useful to policy practitioners. The EU/CST approach, for example, is so ambitious in its breadth that it does not provide any guidance on how to mediate or balance among competing objectives. Neither provides a very clear idea of what a transportation system might look like that achieves its goals, or how it interacts with the larger economic and accessibility systems in which transport is embedded.

2.3. Toward a systems-based vision

A fundamental characteristic of the transportation sector that continually frustrates policy development is the porous nature of the transport system itself. Transportation is not a closed, self-contained system; rather, it is tightly intertwined with other systems. In order for any analysis or project evaluation to occur, transport economists and geographers often bound the system they look at, or else their evaluations would be unmanageable. But by doing so, they are

always at risk—often egregiously so—of committing Churchman's classic 'environmental fallacy':

> "Every problem has an 'environment,' to which it is inextricably united. If you stop x from growing (or declining), you will make other things grow (or decline), and these changes you have created may very well be as serious, and as disastrous, as the growth of x." [6]

A classic transportation example is traffic congestion. Looking too narrowly at particular congestion bottlenecks, without thinking about the system as a whole, can lead to solutions which merely serve to move the choke-points around, rather than those which improve the system as a whole.[2]

Even where transportation is understood and evaluated more or less 'systemically', however, the environmental fallacy is still ever-threatening, because of the nature of transport's open connection to other human endeavors. Changes in the transportation system invariably induce changes in human behavior, changes that analysts who do not acknowledge these larger systems will overlook in their policy assessments. There are many examples of how behavioral change confounds narrowly conceived policies:

- *Induced travel* refers to any increase in travel resulting from an improvement in transportation conditions, and is a natural market response to a reduction in the time-cost of travel. An example of this phenomenon is congestion that recurs sooner than forecasted on a highway that has been widened as a congestion relief measure. While the mechanisms behind induced travel can be quite complex to trace, simple micro-economics can account for it [8].
- *Traffic safety* policy traditionally attempts to minimize the likelihood of injury associated with risky behavior. Adams [9] has suggested that individuals have a certain tolerance for risk, and continually adjust their behaviors to balance perceived risk against anticipated rewards. As a result, 'safety' policies that reduce the likelihood of injury might encourage riskier behavior, thereby exposing others to greater risk than they otherwise would have experienced in the absence of these policies.
- *Technology improvements.* Governments regularly subsidize research into technologies to improve automobile fuel efficiency. For passenger vehicles, these measures are often undermined by consumers' demands for ever-higher performance. The result is stagnant fuel economy, but greater performance [10]. In the freight sector, efforts to improve fuel-efficiency of trucks help reduce the cost of transportation, contributing to greater use of transport as an input to production (e.g. substitution of just-in-time delivery for on-site warehousing).

To the extent that sustainability policy fails to adopt a systems-based vision of its objectives, it risks similar failures. To some degree, the OECD/EST and particularly the EU/CST approaches discussed in the previous section do encourage more systemic thinking about sustainable transport than does the WBCSD approach, because their understanding of the underlying activities to be made 'sustainable' is more expansive. However, these programs do not propose a mechanisms by which a 'vision' resulting from a more expansive vision can be translated into actual policies.

Recently, the EU's Sustainable Mobility, policy Measures and Assessment (SUMMA) project created a way to begin to evaluate sustainable transport proposals. In doing so, it has

[2] Indeed, according to Braess' Paradox, under certain circumstances, capacity increases can cause the transport system's performance to deteriorate, even if traffic levels remain constant [7].

grappled with the synthesis of the sustainability-as-process and sustainability-as-end-point paradigms. SUMMA builds on the EU's 2001 definition, proposing 'outcomes of interest' and indicators relating to the economy (e.g. accessibility, productivity, costs), society (e.g. affordability, livability, equity), and the environment (e.g. resource use, pollution, noise) [5]. To develop these indicators, the SUMMA project relies on an activity-based analytic system comprised of a series of nested or embedded 'markets', resulting ultimately in a derived demand for motorized mobility that is responsive to larger productivity and accessibility systems. The project's market-based approach allows it to be used for integrated assessments of proposed policies that account for their interactions with broader social and economic systems, helping unite the process and end-state approaches in a potentially useful way.

The SUMMA project suggests that 'top-down', comprehensive approaches to sustainability in the transport sector may yet have some life in them, if the promise of process and end-state integration can be realized. On the ground, however, the notion of 'sustainable transport' has also been developing, albeit through a more organic process of trial, error, and innovation. The following section examines some of these trends, and how cities are creating policies to foster them.

3. Implementing sustainable urban transport

Today, hundreds of cities are pursuing sustainable transport strategies—under that banner or otherwise, in isolation or as part of broader sustainability initiatives. The range of actions taken under this umbrella is too diverse to catalogue. Sustainability is being linked to other strategic policy objectives in countless combinations, with impacts on the ground that range from a continuation of business-as-usual to real transformations in the character of urban life.

This section highlights some of the more ambitious and innovative directions that sustainability policy has taken in recent years, and organizes them into four clusters of activity: New Mobility, City Logistics, Intelligent System Management, and Livability, with particular emphasis on innovations in developed counties. This is not intended to be a complete typology of sustainability policies—indeed, there is considerable overlap among the four clusters we propose, and a number of policy issues that are largely left out, such as fuel and vehicle technology strategies. They simply represent the authors' judgments of clusters of innovations that are beginning to consolidate into coherent new visions of sustainable transport policy. These strategic policy visions might take different forms if applied in different cities, where local needs, levels of economic development, cultures, urban forms, economic structures, and transportation systems must be taken into account.

3.1. New mobility

The first emergent strategy deploys creative new technologies and business models to provide competitive alternatives to the private automobile. These 'new mobility' strategies foster new and more efficient ways of moving through and interacting with the city by providing customers with more flexible, convenient and integrated travel options. If successful, these strategies as a whole should reduce the amount of depletable resources consumed, and thus represent a step along a path toward sustainability.

Distributed travel information. Today, most major metropolitan areas are developing intelligent transportation systems that provide real-time information to travelers. These systems can provide information on driving times to downtown, when the next bus will arrive, which arterials are least congested, and which central parking lots have space available. Increasingly,

innovative agencies and companies are beginning to augment and repackage these data and publish them over the internet so that they can be accessed from mobile devices anywhere (e.g. the San Francisco Bay Area's '511.org' system). Google Labs is developing a tool that can pinpoint the locations of taxicabs in a dozen US cities.

Fare integration. Many regions are modernizing their fare payment technologies, while simultaneously unifying their many agencies and modes under a single fare media 'brand'. This strategy includes fare structure simplification, inter-agency fare payment integration, adoption of time-saving fare collection technologies, and implementation of 'smart cards' with multiple uses (e.g. parking or carsharing payments, or even as a cash alternative). These improvements cut barriers to transit access, encourage participation in monthly pass programs, and potentially serve as new revenue sources for transit agencies. London, Paris, Bremen, and other cities have all undertaken ambitious fare integration and branding strategies.

Carsharing provides access to automobiles as a subscription service, allowing customers to reserve vehicles by the hour, over the phone or the Internet. Both carsharing businesses and non-profit 'car clubs' are beginning to thrive throughout the US and Europe. They provide the convenience of inexpensive access, reserved parking in local neighborhoods, and a variety of trendy and fuel-efficient vehicle models. They also provide significant environmental benefits by helping maintain or expand the public transportation user base [11,12]. San Francisco, Philadelphia, and many European cities actively promote carsharing, by providing subsidized or preferential parking, or contracting with carshare groups in place of maintaining large municipal fleets. Carsharing is a fertile area for innovation. In California, researchers are exploring business models for the suburbs, such as arranging for families, commuters, and employers to share cars at different times of day on an ongoing basis [13]. In Berlin, experiments are underway with 'cash cars': participants lease vehicles for their personal use from dealerships, and loan them to carsharing groups when they are not needed (in exchange for half of any revenue) [14].

Bikesharing. Deutsche Bahn, the German railway company, offers 'Call-a-Bike' programs in Berlin, Frankfurt, Cologne, and Munich. Self-locking bicycles are distributed around the city, and may be unlocked by calling a phone number and entering a code and credit card information. Customers are charged by the minute, the day, or the week. Customers can also use their cell phones to locate the nearest bikes. In Lyon, the bikes are equipped with sensors that automatically diagnose and report maintenance needs.

Auto-Free Housing. Some cities provide incentives for reduced auto ownership. In the San Francisco Bay Area, some cities have granted developers density bonuses or exceptions to minimum parking requirements for new rental housing at transit hubs, on the condition that tenants pledge not to own cars. Some of these developers, in turn, have offered carsharing as a marketing tool for these developments. The practice of reducing off-street parking requirements for developments that provide access to carsharing has also been seen in Bremen and other German cities [15].

New service paradigms. In the emerging networked economy, retailers have learned to compete in new ways by reorganizing around customer needs, adapting continuously, and cultivating brand loyalty [16]. Transit agencies, too, are beginning to reinvent themselves around this model [17]. No longer just providers of service, many now seek to act as 'integrated mobility' service providers, ensuring a reliable, convenient, efficient and 'seamless' experience from origin to destination. They are developing partnerships and marketing strategies so that they can more effectively compete for discretionary travelers.

Paris has been in the forefront of this approach [18]. Its transit agency, the RATP, provides real-time, door-to-door online journey planning for its rail and bus routes. This service will

eventually deliver information about all modes, as well as information on entertainment, cultural institutions, and other services. It is evolving into a seamless mobility service, integrating traditional transit offerings with bike rental, paratransit, carsharing and carpooling services. In its stations, it provides amenities to minimize the inconvenience of waiting, and will soon provide cell phone and internet service throughout its network. Its new, integrated smart cards feature distinct branding strategies and packages of benefits for youth, adults, seniors, and tourists.

3.2. City logistics

Urban freight traffic is growing fast. E-commerce has facilitated the rapid growth of the small package delivery business. Increasing numbers of trucks on the road are below capacity or running empty, because of rapidly changing logistic and supply-chain pressures, such as just-in-time deliveries, as well as asymmetrical patterns of trade. Sustainable urban freight policy seeks to reduce empty truck movements through neighborhoods and congested urban centers, and improve the environmental and economic efficiency of urban freight operations. As with carsharing, these policies are a fertile area for cooperative public-private-university research and pilot projects. They can take many forms [19]:

Neighborhood drop-off points can significantly reduce trips associated with residential deliveries. They can be as simple as a dedicated counter in a local shop, or as high-tech as 'Tower24' in Dortmund, Germany, a fully automatic storage facility where neighbors can collect their packages 24 h a day.

Centralized urban distribution and logistics centers provide cooperative local delivery of goods, often using clean fuel vehicles. Tokyo has operated public distribution centers since the 1960s. In the 1990s, several European cities experimented with coordinated goods distribution. Many of these projects were short-lived, but some remain. In downtown Monte Carlo, Monaco and Bremen, Germany single municipal carriers now make all deliveries from centralized depots. Nuremberg and Freiburg, Germany and Bristol, UK have encouraged (and in some cases subsidized) voluntary, private cooperatives among shippers or major retailers to coordinate deliveries. A number of Dutch cities have set up licensing schemes whereby participating firms receive certain privileges (e.g. longer delivery hours) in exchange for performance commitments (e.g. using only electric vehicles, and exceeding minimum loading standards). Berlin has taken a block-level approach, encouraging neighboring retailers to make cooperative delivery arrangements, and then customizing loading and parking areas to meet the businesses' needs. The positive effects of such programs can be substantial; in Bremen, the number of truck trips into the city was cut by about 70% [20], while Freiburg's program reduced truck journeys by 33% and truck operating times by 48% [19].

Stockholm's Hammarby Sjöstad development (a model sustainable city for 20,000 residents and 10,000 workers in an old industrial area near downtown) attempts to take city logistics a step farther. As in other programs, deliveries to the community will use electric vehicles coordinated through a privately operated logistics center. In addition, this center will operate a web-based service featuring 15 local businesses and 300 local farmers, from which it will deliver everything from food to dry cleaning services. Suppliers or shops pay the center by the shipment; participating households pay a monthly subscription fee. The early success of this program has led nearby Old Town Stockholm to pursue its own logistics center.

Construction logistics. During the massive redevelopment of Potsdamer Platz, the municipal authorities of Berlin required that concrete be produced on-site, and that the bulk of materials be moved to and from the site by rail. This requirement led to the establishment of a logistics

company charged with coordinating freight transportation services at the site. The result was so successful that the project was completed 6 months early, and logistics coordination was adopted as national policy for major construction projects throughout Germany [14]. This model was also replicated in the construction of Stockholm's Hammarby Sjöstad project discussed above.

Environmental zones. Many European cities, such as Copenhagen, Stockholm and Amsterdam, restrict use of downtown loading zones for trucks over a certain age, or that do not meet strict emissions standards. In 2002–2003, Copenhagen experimented with an elaboration of this policy with a pilot environmental pricing scheme called the 'City Goods Ordinance'. Under this program, use of the loading zones in the medieval city center required payment of a daily charge. Longer-term, reduced-cost permits were available for vehicles that could meet certain vehicle age, size and/or capacity utilization standards.

3.3. Intelligent system management

Many cities are introducing new pricing and system management techniques to achieve greater environmental and economic efficiencies. The success of such techniques can help contribute to urban sustainability by ensuring that the historical centers of metropolitan areas remain economically competitive. Perhaps the best known example in recent years has been London, under the leadership of its mayor, Ken Livingstone. London's comprehensive transportation policy [21] touches on virtually all of the themes in this paper, but its most innovative components focus on revolutionizing transportation system management.

Congestion charging. London's most ambitious policy is its congestion charging scheme, adopted in 2003. Vehicles used weekdays in Central London are subject to a £8 daily charge, enforced by a network of cameras and computer recognition of license tags. Revenues from the charges help improve transit service and finance other transport improvements. The congestion charge has been so successful at reducing congestion in Central London that it has actually fallen short of its revenue forecasts, and has inspired other cities such as Stockholm to consider congestion zones of their own. The city is now considering enlarging the cordon, and the UK government is proposing a road pricing scheme for all of Britain.

Comprehensive bus system management. In order to address the increase in bus riders expected due to the congestion charge, Transport for London, the metropolitan area's public transport coordinator, began to increase and transform bus service throughout London. It increased service frequencies (using revenues from the congestion charge), and established the London Bus Priority Network, an 860 km system of streets managed and enforced to maximize the efficiency of bus service. It launched the London Bus Initiative to provide a highly reliable, 'whole route', interagency approach to enhancing and enforcing bus services. This initiative envisions creating 70 'BusPlus' routes that feature enhanced passenger information, real-time bus arrival displays, low floor buses, more regular cleaning, modern bus shelters, transit priority traffic signals, and automatic vehicle location and driver instruction systems to reduce bus bunching and improve reliability. The city is also revamping how it procures bus services, by introducing 'Quality Incentive Contracts' that include financial incentives for operators to improve the quality and reliability of the services that they provide, and attract additional ridership.

Automated traffic enforcement. Traditional approaches to traffic enforcement require a large commitment of police and judicial resources, especially given the evidentiary and procedural requirements for criminal prosecutions. In addition, enforcement actions themselves may exacerbate traffic conditions on busy streets. For these reasons, many cities around the world are

switching to camera-based enforcement of speed limits, red lights, and other traffic laws. After detecting violations, these systems use license plate recognition to identify and mail citations to vehicle owners. Cases are typically prosecuted less expensively through the civil courts.

London applies this strategy to enforce its congestion charge and to maintain the effectiveness of its Bus Priority Network. For the bus lanes, fixed and bus-mounted cameras detect and film vehicles illegally using bus lanes, generating evidence for enforcement through the civil courts. Together with the introduction of the congestion charge, the adoption of automated bus lane enforcement has dramatically improved the speed and reliability of bus service in Central London.

Business plans. London's focus on efficient management extends to the ways it evaluates its own proposals. Both Transport for London and the local boroughs are required to make their transportation spending proposals in the context of 'business plans' that emphasize consistency with the achievement of the region's policy objectives. Internally, Transport for London requires that a 'business case' be made for every policy or capital investment, including the social and environmental benefits that it provides.

3.4. Livability

A fourth realm of innovation focuses more directly on the relationship of the transportation system to society. We cluster these innovations under the title 'livability', which includes concern for accessibility, the allocation and design of public space, opportunities for social engagement and recreation, and the overall health and economic welfare of city residents. It embraces the idea that hyper-motorization erodes the social and economic vitality of a city, and emphasizes accommodating the automobile, without privileging it over other uses of public space. Related recurring themes include improving in accessibility and recreational options for children, and promoting physical activity to combat the public health crisis posed by obesity [22].

Many of these initiatives have been innovated in the Colombian capital of Bogotá, especially under the leadership of Enrique Peñalosa, mayor from 1998 to 2000. During his tenure, Bogotá began the transformation its infrastructure around a vision of livability, social equity, and reclamation of public space [23].

Pedestrian realms. Bogotá has a long tradition of closing many of its roadways on Sundays to motor vehicles, so that they can be used for recreational purposes. Recently, it also began developing a permanent network of streets exclusively for the use of bicycles and pedestrians. It built 'Alameda Porvenir', the world's longest pedestrian and bicycle roadway, stretching 18 km through the urban center, poor neighborhoods, and out beyond the city's developed limits. By creating a grand non-motorized promenade in advance of development, it hoped to create a transportation, social, and recreational resource that would shape the city's future evolution. It also banned parking on sidewalks, began an extensive network of bicycle paths, reined in the colonization of plazas by street vendors, and fostered the use of sidewalks as public spaces.

Breaking the driving routine. Bogotá has also developed a number of strategies for preventing its residents from becoming habitual car drivers. The city observes annual 'car free days', helping its citizens to become familiar with transit or non-motorized alternatives for their daily routines. Bogotá also rations the privilege of driving in the city during peak hours, by requiring each car to be removed from the city's streets two days a week.

Bus rapid transit. Bogotá has developed a sophisticated, highly efficient, and large-capacity bus rapid transit system, the Transmilenio. Transmilenio builds on concepts pioneered in

Curitiba, Brazil, but at a larger scale. Already profitable and rivaling the passenger volumes of large urban rail systems, its network is envisioned to reach within half a kilometer of 85% of Bogotá's residents. By creating a ubiquitous, inexpensive, high-efficiency transit system, Bogotá hopes to maximize its poor population's access to employment and other opportunities [24].

Shared space. Many other cities have developed their own approaches to livability. The United Kingdom, Denmark, Sweden, Germany and the Netherlands have seen numerous cities and towns redesign neighborhood streets to create 'home zones' or 'woonerfs'—areas where cars, bicyclists, and pedestrians coexist on equal terms [25]. Unlike conventional traffic calming techniques that add infrastructure to slow traffic, home zones and similar strategies promote shared spaces. These can significantly improve traffic and pedestrian safety, encourage use of non-motorized modes, create a more aesthetically pleasing urban landscape, and foster greater opportunities for social interaction in public spaces [26].

4. Concluding observations

The preceding section reviewed four emerging clusters of practice that outline potential visions or models of sustainable urban transport. Each is an example of the improbable: an inexpensive, quickly implemented, politically popular, and effective sustainable transport strategy. These four clusters of innovation emerged from observing innovative practice on the ground. At some point in the future, these or other innovative directions may themselves become a part of the definition of sustainable transport itself.

The four approaches share a number of common elements that will be critical to their success:

Systems perspective. Each of the four approaches brings a different systems view, either by acknowledging the interaction between transportation and other social and economic systems, or by adopting a more comprehensive view of the transportation system itself.

- The 'New Mobility' cluster addresses how individuals plan their daily activities. It seeks to understand and influence the full array of economic and psychological factors shaping mode choice and vehicle ownership decisions in the context of these activity patterns.
- The 'City logistics' cluster addresses the business of goods movement. Though in its infancy, and facing the difficult challenge of fostering cooperation among competitors, its early successes suggest the feasibility of fostering new business models for more sustainable urban delivery systems.
- The 'Intelligent System Management' cluster addresses the relationship between infrastructure and the public institutions that operate it. It seeks to reorganize government around managing public infrastructure as a valuable asset whose value is maximized if it is priced, enforced, and managed effectively.
- Finally, the 'Livability' cluster addresses how society interacts with transportation systems. It advocates greater integration of transportation planning with societal needs, including opportunities for recreation and social interaction, and accessibility for children and the poor.

New institutional requirements. The policies discussed here involve significant challenges to the traditional ways that transportation agencies define their missions, and organize their work. The transformation of public transit agencies from organizations that operate vehicles into customer-oriented 'mobility managers' requires a shift in organizational culture. The use of livability and social welfare as organizing principles in transportation policy are similarly radical challenges to organizations that measure their effectiveness in terms of passenger-kilometers

of service provided. City logistics involves local government intervention in a realm in which it is relatively inexperienced—and therefore requires collaboration and partnership with the private sector.

Bus rapid transit provides an example of the institutional challenges of innovation. In developed countries, traditional bus service has long suffered in many cities due to the fragmentation of authority among, for example, one agency responsible for regulating and managing streets, another agency responsible for enforcing those regulations, a third responsible for operating transit services, and sometimes, a fourth responsible for planning and regulating that service. In many cities, the successful implementation of bus rapid transit has required (or has been preceded by) the functional merger of two or more of these responsibilities, so that a single agency or coordinating body sets policy for the planning and real-time management of bus corridors. This type of institutional adaptation is at least as complex to implement as any engineering challenge related to the redesign of streets for BRT.

Low-cost and incremental innovations. Shifting a city's evolutionary momentum in a new direction requires big ideas. But in transportation, where the results of big projects are rarely correctly foreseen, pursuing sustainable transport through major capital projects provides no guarantee of success. By contrast, none of the four policy visions discussed here involve transportation megaprojects, or envision massive increases in transportation system capacity. They are all intended to be implemented quickly, incrementally, and at low cost.

In fact, innovation itself may prove to be the most promising path to sustainability. Each of the four models discussed in this paper represents only a fraction of many innovative efforts underway around the world. New ideas are continually being tested; many fail, but the best ideas thrive and are adapted elsewhere. The lesson of these efforts is that the key to sustainable transport will be leadership from political figures and policy professionals who have the optimism and vision to innovate, and the courage to learn from occasional failures.

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Todd Goldman is Associate Director for Research of the City University of New York (CUNY) Institute for Urban Systems and Assistant Director for New Initiatives at the University Transportation Research Center. He has a doctorate in City and Regional Planning from the University of California, Berkeley.

Roger Gorham is a consultant and former transportation policy specialist with the US Environmental Protection Agency. He has worked with the World Bank, and as a consultant for the International Energy Agency, the United Nations, the European Conference of Ministers of Transport, the InterAmerican Development Bank, and others. He has a Master of City Planning and a Master of Science in Transportation from the University of California, Berkeley.