

## REVIEW ARTICLE

# Smooth integration of transport infrastructure into urban space

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### ABSTRACT

Municipal authorities in industrialized and in developing countries face unceasingly the issues of congestion, insufficiency of transport means capacity, poor operability of transport systems and a growing demand for reliable and effective urban transport. While the expansion of infrastructure is generally considered as an undesirable option, in specific cases, when short links or ring roads are missing, new infrastructure projects may provide beneficial solutions. The upgrading and renewal of existing networks is always a challenge to the development of a modern city and the welfare of citizens. Central governance and management of transport systems, the establishment of smart and digital infrastructure, advanced surveillance and traffic monitoring, and intra-city energy-harvesting policy are some of the steps to be taken during the transition to a green and sustainable urban future.

Municipal authorities have also to consider other options and strategies to create a citizen-friendly setting for mobility: diminish the need for trips (digitalization of services, e-commerce, etc.), shift from private to public transport and transform the urban form to promote non-motorized transport in favor of the natural environment and public health. A citizen-friendly policy based on the anticipation of future needs and technological development seems to be a requisite for European cities searching for a smooth integration of their networks into urban space.

**Keywords:** *city; transport; infrastructure; congestion; pollution; engineering; integration; environment*

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## 1. Introduction

Transport provides vital connectivity services in industrialized and in developing countries, facilitating mobility and enabling economic growth. As by general rule, transport means and infrastructure have to respond to growing mobility needs, all by respecting environmental constraints and aiming at social acceptance (World Business Council for Sustainable Development, 2009). To this end, transport authorities, at local and national levels, are driven to implement new logistic concepts establishing transport modes' seamless interconnection and to design new infrastructure accommodating spatial-economic growth and urban expansion.

In industrialized countries, the actual stake with respect to transport networks is the functional upgrading of the existing infrastructure.

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Additional links may also be, in several cases, necessary, while innovative technology is always a precondition for high serviceability. In developing countries, the construction of new transport corridors is a permanent requisite and, also, a puzzling issue. Lack of financing is the most common impediment to this end (The Economist Intelligence Unit, 2019).

Whether dealing with the renewal of the existing infrastructure or with the construction of new corridors, this infrastructure development must fulfill key societal requirements, such as net social benefit, balanced occupancy of public space and environmental sustainability so as to effectively respond not only to end-user needs but also to non-user needs. Effective integration of these key requirements into every transport infrastructure project is complex. Difficulties grow bigger in the case of urban areas, these enormous and multiple intersections of links and corridors, where local, national and international transport corridors have to comply with ordinary urban activities.

As mobility demand grows in flourishing cities, fundamental issues related to transport infrastructure arise: when is an extension of the existing infrastructure necessary? Are new transport infrastructure projects realistic in compact cities? Will an extended transport infrastructure be beneficial to the community and to the environment? What other options may prove effective? What about innovation and smart technology for existing networks with a view to enhanced mobility?

In most European cities, the extension of the existing infrastructure to accommodate growing demand in mobility is rarely a realistic option. Alternative solutions advocating for non-motorized transport and for broader use of mass transit systems usually prevail. However, in specific cases, the grade separation at an intersection, the construction of a missing link, the upgrading of a declining corridor may still constitute rational perspectives. If such is the case, municipal authorities and transport infrastructure engineers have to consider the impact of new transportation structures on the environment and the society but, also, to engage in innovating existing urban links and nodes by smart technological solutions.

This multifaceted approach to the issue of growing transport needs in cities is the scope of this paper: optimizing the performance of existing and upcoming transport infrastructure in the urban space by engineering and technology, but also by a transition policy, with care for the preservation of the environment and for social welfare.

## **2. Actual state of integration of transport corridors in European cities**

Transport networks are defined and evaluated by performance indicators related to a) connectivity, operability and serviceability; b) environmental adaptation and spatial planning; c) social acceptance and impact and d) pricing policy, cost-effectiveness of investment and financing needs (Yatskiv and Budilovich, 2017). In this sense, and with a view to optimizing the performance of the infrastructure, transport authorities have to deal with increasing needs for seamless mobility, travel comfort and cost reduction, while, at the same time, municipalities, engineers and communities have to take into consideration present-day issues related to the environment and climate change.

Convincing and effective responses to these major issues, as well as prospective improvement of the performance of urban transport networks, are persistent challenges for municipal and regional authorities. In Europe, despite the high operability of transport networks in the western part of the

continent, basic and primordial issues regarding the urban transport networks are still open: urban and regional road networks across Europe can hardly be identified as fully operational in terms of innovation and serviceability. In some countries, where the emergence of motorways absorbed the totality of public investment in road infrastructure, the significant upgrading required by the rest of the networks is restrained by lack of funds (Kehagia and Mouratidis, 2012).

In general, transport infrastructure projects, meant to provide additional space for traffic lanes or rail corridors in the urban space, are hardly the best option to face growing mobility. Expansion of infrastructure can generate an increase in demand for mobility and will certainly degrade the urban space. By contrast, the construction of specific missing links and innovation of transport nodes have, in most cases, a beneficial impact on mobility and society. Moreover, in countries of the European Union, non-motorized traffic is seriously encouraged by adequate measures and funding opportunities.

Dealing with the preservation of the environment in the transport sector, it must be clear that the political aspect is of equal importance to the societal aspect: setting maximum air and noise pollution standards will be useless unless there is the political will and regulatory resources in place to enforce them. Nor will the premature introduction of costly low-carbon fuel alternatives aid the poor if bus fares increase as a consequence (Cervero, 2013).

In the era of informatics and digital technology, municipal authorities and communities in Europe must also consider more innovative means for accessing services, education and marketplaces but also for providing labor and expertise. Much more, a decisive step forward resides in the transformation of the city enabling citizens to minimize trips. The smooth functioning of an urban network requires the integration of smart technologies into the transport sector, including equipment for digital information, ITS for traffic management and transmodal communication systems (European Commission, 2013).

### **3. Integration of transport networks by engineering operations**

The transport network in an urban and per-urban space generally consists of streets and roads, railways and metro lines, airports and waterways (Rodrigue, 2020). Growing mobility demand may reasonably lead to more transport links and larger terminals. Finding creative and effective solutions to keep up with public space constraints is a very significant issue.

Urban transport professionals will face major challenges in the decades to come. They are expected to facilitate the transition from primarily car-based mobility to the mobility of at least the same quality level but based on walking, cycling and collective passenger transport. They should offer better and more sustainable mobility and transport services to users. They should find solutions to mitigate the negative impacts of transport on citizens' health and well-being, the environment and climate (**Figure 1**).

Finally, urban mobility professionals need to balance the desire for short-term improvements with the ambition to develop a strategic and sustainable planning perspective for their cities. In many cases, these tremendous challenges need to be approached under severe financial constraints due to the present economic crisis and strained public budgets (Civitas, 2012).



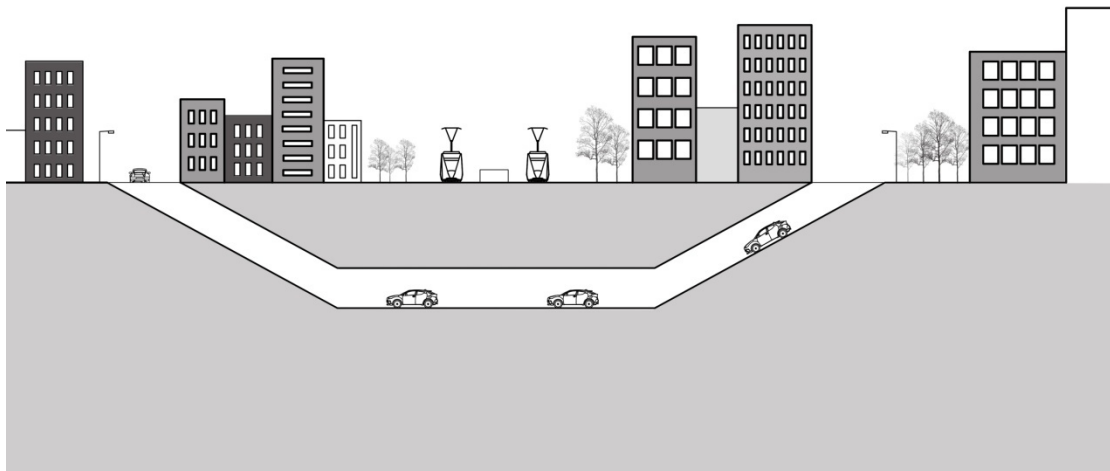
**Figure 1.** Upgraded local street for revitalization of urban area

Although traffic engineers' view on prospective expansion of any urban road network is totally negative, it seems that construction of new links may prove, in specific cases, beneficial to traffic flow conditions and to the mobility of citizens. These cases are:

- Local streets for the revitalization of declining city areas. They aim at the revival of shrinking urban areas by smooth traffic, inflow of pedestrians, and environment-friendly assets (Figure 1).
- Ring roads, which provide a by-pass to vehicles around the city, thus reducing traffic congestion in the city center. In the case of congested urban arterials and streets, the alternative of ring roads for long-distance trips may be an option. In specific cases, a “fly-over” (an elevated long bridge) may also be a beneficial solution to accommodate increasing traffic (Mouratidis, 2020).
- Short local links against fragmentation of the city, mostly created by transport (urban freeways, rail lines). Missing links of decisive importance may prove necessary and beneficial to traffic conditions in the urban space. Short road tunnels are usually the best option in this case (Figure 2).
- Subsurface corridors to replace traditional urban arterials, thus yielding urban space to green areas (parks, municipal gardens).

In the domain of rail transport, the enhanced capacity of rail corridors is also a crucial issue. Competent authorities must jointly work out plans of exploitation of full capacity of links and nodes, before adopting a strategy for the construction of new infrastructure, by:

- a. Using limited and absolutely necessary infrastructure corridors (same track line for inter-urban, peri-urban and local rail, and sub-surface metro lines).
- b. Exploiting for the full capacity of transport links (extend schedule to 24 hours, accurate planning of services).
- c. Designing and constructing environment-friendly solutions in urban space (electrification, noiseless rail lines, smooth intersections, “green” context, “green” roofs over railway tracks).



**Figure 2.** Road tunnel to shorten by-pass route around railway station

With regard to the existing infrastructure, a variety of operations may lead to the environment- and citizen-friendliness of transport assets. Green pavements (**Figure 3**), elevated medians, woonerf and pedestrian streets, limitations to on-street parking and exploitation of interspace between trees on sidewalks (**Figure 4**) are some of the interventions that are meant to turn an uninviting city into an urban settlement respectful to citizens and visitors.

These operations have a beneficial impact on society and public health, the natural environment, energy savings, traffic safety, mobility of citizens and accessibility to transport systems for all (**Table 1**).



**Figure 3.** Green pavement

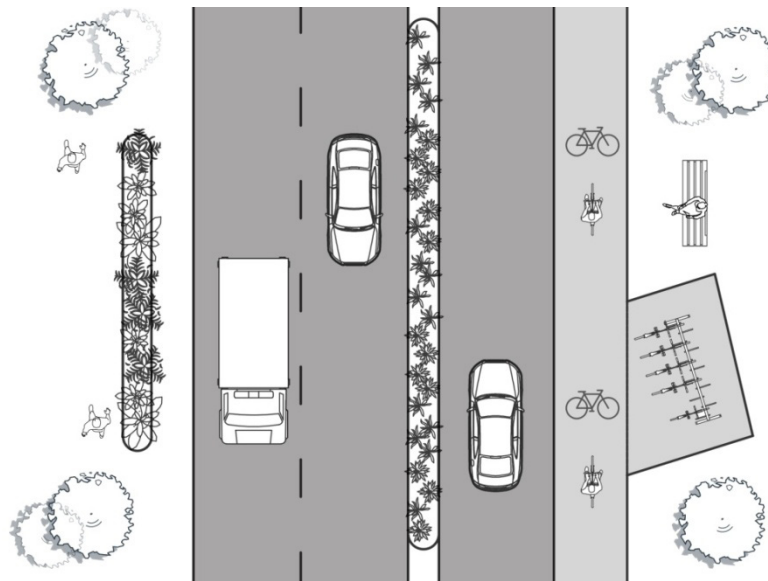


Figure 4. Environment-friendly exploitation of public space

Table 1. Impact of engineering operations on society- and environment- friendliness of infrastructure

Engineering operation	Criteria of performance				
	Social acceptance and public health	Natural environment	Energy and economy	Traffic safety	Mobility and accessibility
Smooth pavements	++	+	-	-	-
Green pavements and sidewalks	+	++	+	-	-
Elevated medians	-	-	-	++	+
Colored pedestrian crossings	+	-	-	++	+
Infrastructure from recycling	-	++	++	-	-
Infrastructure for non-motorized transport	+	+	+	+	+
Lowering speed limit	-	-	(+)	++	+
Woonerf streets	+	+	-	+	+
Ev charging stations	+	(+)	*	-	-
Urban roundabouts	+	+	-	++	++
Limitation to on-street parking	(+)	-	-	+	++
Rainwater conservation	-	++	+	-	-

Legend: ++ significant impact; + moderate impact; (+) insignificant impact; - none

## 4. Policy considerations for greener transport infrastructure

Achieving a smart, green and integrated transport system is essential to developing the social-economic and environmental sustainability of European urban centers. Transport corridors, urban streets, nodes and terminals must be adapted to new standards through adequate measures, mostly by introducing smart and digital technology. The real challenge, however, is that municipal authorities and stakeholders must think and act “out of the box”—in brief, beyond the uncertain effectiveness of ordinary construction projects. This is the only way to transform the serviceability and the social acceptance of urban functions, including transport operations. In this sense, central governance of means and infrastructure as well as innovative urban planning are cornerstones of a transition policy for a changing and improving city.

Specific priority topics in the frame of a versatile transition policy, aiming at an effective integration of links and nodes in an urban context, are identified as follows:

- a. **Central governance and management:** Single-mode transport networks are often directed and managed by different authorities. These may be public bodies, private companies, concessionaires and PPP schemes. Coordination of roles, services and management by one single authority is decisive to the operation of multimodal and unimodal networks and critical to the serviceability and reliability of transport systems and infrastructure.
- b. **Complete multimodal terminals:** Terminals may be points of interchange within the same modal system (Rodrigue, 2020) but they may also be points of shifting to another mode of transport. Urban terminals must provide multimodality to passengers and contribute to better mobility services in a citizen-friendly city.
- c. **Reliable mass transit:** Citizens and visitors will shift to mass transit if public transport means and infrastructure are convenient and reliable. Waiting time, comfort, and accuracy of schedule are criteria to attract passengers in mass transit. Digital information to be displayed in mass transit means and terminals, at bus stops and metro stations is essential to improve urban mobility.
- d. **Traffic monitoring and information to drivers:** ITS technologies for traffic control and safety, digital information for drivers and anti-congestion policy by alternative routes improve traffic flow and reduce congestion in urban space.
- e. **Urban planning:** Intra-urban trips may be avoided or shortened by suitable urban planning. Urban sprawl and hyper-centralization of public services generate useless and long trips in a city, thus increasing congestion and air pollution.
- f. **Smart maintenance of infrastructure assets:** Monitoring of structural and functional serviceability of the infrastructure, application of “digital twins” technology and least- or non-intrusive maintenance methods are key components of this priority topic.
- g. **Pricing policy:** Municipal transport authorities are supposed to efficiently deal with the management of internal and external costs; by rational management, they strive to minimize maintenance and operation expenses along the urban networks. In the field of revenues, they must also establish a citizen-friendly toll and parking fee policy and find a fair balance between affordability and sustainability of public transport fares.

- h. **Digital public services:** Digitalization of public services enables citizens to submit forms and applications online and to receive the requested official documents in the same way. The convenience of digital services over paper-based ones is undeniable and spares citizens unnecessary trips.
- i. **Congestion pricing:** Congestion pricing allows surcharging of users of private vehicles in periods of peak demand. The charges are related to the negative external costs (impact on the environment and congestion) that each vehicle creates, and hence can easily be justified on equity grounds. Congestion pricing reduces traffic flow, while consumers have incentives to prioritize trips, that is, avoid marginal value trips or switch to other modes of transport (Anand et al., 2017).
- j. **Monitoring noise and air pollution:** Air and noise pollution often originate from the same sources, such as traffic, machinery used on construction sites, and local point sources, such as power plants and generators. Monitoring these indicators of well-being of citizens may lead to restraining measures related to urban traffic.
- k. **Updated emergency and evacuation plans:** European cities are gradually struck, more and more often, by natural and man-made disasters. Natural disasters, such as wildfires, floods, hurricanes and storm surges, driven by climate change, are likely to devastate urban centers in the years to come. Cities need elaborate plans of not only traffic measures, in case of emergency, but also evacuation plans to allow smooth outflow of vehicles, in case of a major disaster.
- l. **Sustainable energy sources:** In the last decades, renewable energy technologies have achieved massive technological advances and sharp cost reductions. Renewables have come to the forefront of the global energy transition, with nearly every country adopting a renewable energy target (International Renewable Energy Agency, International Energy Agency and REN21, 2018). The challenge for municipal authorities is to provide incentives for the production and use of renewable energy in the metropolitan area of a city and to mobilize research and innovation for energy-harvesting transport infrastructure.

The impact of these policy options on the criteria of performance of urban transport networks is shown in **Table 2**.

## **5. Innovation and research**

Transport infrastructure authorities must effectively address most of these challenges to ensure the smooth operation of an urban transport network. In concerted actions with experts and researchers, they must elaborate strategies and make use of innovative tools in this regard, such as telematics, digital technology and artificial intelligence. The challenge for the competent transport authorities is continuous and recurring and requires unceasing consultation with experts and coordinated transnational actions for innovation (Kehagia, 2021).

Without innovation and research supporting infrastructure construction and renovation, the only option is to keep on building infrastructure the 20th century way—high carbon, low innovation and at high cost—all very wasteful, inefficient and with no way or hard ways to support innovative transport modes. It is therefore vital to improve infrastructure delivery for people and freight,



**Table 2.** Policy options to effectively integrate transport networks into urban space

Policy option	Criteria of performance				
	Social acceptance and public health	Natural environment	Energy and economy	Traffic safety	Mobility and accessibility
Complete/ multimodal urban terminals	+	(+)	+	(+)	++
Reliable mass transit	++	+	+	+	+
Innovative urban planning	+	+	+	+	++
Traffic monitoring and information to drivers	(+)	+	-	+	++
Digital public services	++	(+)	+	-	+
Congestion pricing	+	+	+	-	++
Monitoring noise and pollution	++	++	-	-	-
Central governance and management	+	-	+	(+)	++
Innovative maintenance for the infrastructure	(+)	-	+	(+)	++
Pricing policy (mass transit, parking lots, urban tolls)	++	-	+	-	+
Updated emergency and evacuation plans	+	-	-	++	++
Sustainable energy sources	+	(+)	++	-	-

Legend: ++ significant impact; + moderate impact; (+) insignificant impact; - none

moreover for becoming globally competitive. Across Europe, there is an urgent need to modernize construction delivery (Zarli et al., 2016) and get cities ready for upcoming challenges, such as “electric air taxis”. This may seem far too distant nowadays but it seems that the market for flying cars or electric *air taxis* is expected to continue growing during the present decade, and this travel mode will be a rather trivial solution to intra-and peri-urban trips by 2030. Take-off and landing facilities can be established on public buildings, terminals, health centers and other locations to accommodate this upcoming transport means.

By a general rule, anticipation on upcoming development in technology and innovation will facilitate the transition of a city from the state of inconsiderate expansion, creating congestion, pollution and time waste, to a sustainable condition of a citizen-friendly urban center of the 21st century.

## 6. Conclusion

Municipal authorities in industrialized as well as in developing countries are seriously concerned about traffic congestion, insufficiency of transport means, and air pollution. In search of citizen- and environment-friendly solutions to these problems, they must act on two distinct directions: the engineering direction, comprising measures and operations in an engineering sense, and the institutional direction, consisting of a set of initiatives going far beyond construction projects' boundaries. In this more general context, municipal authorities have to consider other options and strategies to create citizen-friendly mobility: diminish the need for trips (digitalization of services, e-commerce, etc.), encourage shift from private to public transport and transform the functional structure of the city by promoting the use and also the harvesting of renewable energy. This decisive and necessary step requires a fundamental change in transport policy for big urban centers. It requires a policy based on the determination to provide a high serviceability and environment-friendly urban context to citizens and on the anticipation of future needs for mobility in a changing world. This transition policy regarding urban transport seems to be a requisite for European cities searching for a smooth integration of their networks into the urban space.

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