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Low Carbon stations for Low carbon cities

Quick-scan desk research on trends, challenges and opportunities in adapting urban interchanges for low carbon future

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MISTRA URBAN FUTURES

Mistra Urban Futures is an international center for promoting sustainable urban futures.
Its headquarters is located in Gothenburg, Sweden. The center operates in five cities in the world, including Cape Town, Gothenburg, Kisumu, Greater Manchester and Shanghai. We believe that co-production of knowledge is a winning concept for achieving sustainable urban futures and creating Fair, Green and Dense cities.

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Translating a literary copy by computer can you give you a newsletter, translating a poem by computer can give a memo. Likewise, if you plan a city focussing only on bricks, walls, corners, bridges, platforms and tunnels you create pockets, isolated environments, secluded areas, ghettoes.

Cities are made by and for people. Each city has its genetic code. The DNA of cities is composed of traces, memories, victories and sadness, of different layers, routes and walkways, of networks, synergies and open spaces.
When regenerating or modernising urban space it is essential to consider the language of these human experiences, and endow them a space.

Foreword

High carbon emissions and climate change affect the quality of life in most cities and regions in the world. This threat has become tangible: we are witnessing the destruction of biodiversity, more extreme weather conditions and an increase of health problems linked to pollution and lack of diversity. As one of the biggest contributors to the high carbon emissions is ever growing motorized transportation of people and goods in and around large cities, causing heavy air pollution and traffic congestion, leading to losses in time and money.

Neither road expansion nor the development of new car concepts, or bus technologies in themselves can solve the problem; in fact, these strategies have to be implemented simultaneously to the development of effective non-motorized traffic, user-oriented public transport facilities and transit-oriented neighbourhoods. A transversal and multi-levelled approach is one of the keys to Low Carbon Cities.

At the very heart of a Low Carbon City is the Public Transport Interchange, a station where different transport modi are combined under one roof or in the direct vicinity. Broadly defined, this kind of station is a complex spatial structure that combines different motorized, non-motorized and rail-bound types of traffic with a city's public space. Although the term "interchange" is currently widely used for large physical areas such as central railway stations where other means of PT are available as well, the availability of a variety of transport modi should not be reserved for just these structures or spaces. In the context of low carbon cities, the emphasis lies on improving public transport at all levels, thus local public transport nodes should also be seen as important small-scale interchanges, even if they combine only one or two possible modal combinations. Again, the strength of the system depends on the strength of it smallest element.

Making better non-motorized (e.g walking, cycling) connections to convenient stations, and improving the facilities for every transportation mode is one of the main challenges for adapting a interchange stations for a low carbon future.

Considering design is the most visible, though not the only, part of the qualities of an interchange, in this research we build on prior research conducted by Yellow design Foundation into the link between perceived security and design of an intermodal station and extend it to other fields of expertise in order to create better synergies and performance. Former research by Yellow design Foundation lead to the definition of SPIN-UP (Security Perception of Intermodal stations for Urban Public Transport) an assessment methodology for public space and public transport space.

To be sure, in this respect we refer to the assumption that a well-designed interchange is also a more effective and efficient interchange that can generate different sources of activity, of energy and eventually of income to the city and its stakeholders.

The design of a new interchange station or the conversion an existing station to a structure that is more compatible with the demands of a low carbon city is a complex and multidisciplinary task. The list of technical requirements for achieving multimodality, interconnectivity, a sustainable station building and quality public space is considerable.

Equally important are the "invisible forces" and often non-measureable parts of developing an interchange, i.e. the human programming, the neighbourhood synergies and user appropriation of the site. In this respect we refer to the interpretation and perception by its users, their memories, the linguistic references, its socio-cultural context (as stated by Nijs and Daems, in "And What if the Tangible Were Not, and Vice Versa? On Boundary Works in Everyday Mobility Experience of People Moving Into Old Age",

published in Space and Culture 2012). The user acceptance and interaction with the interchange will co-define its success as a semi-public space.

Putting the user and his needs first is therefore an essential criteria in the process of creating a interchange, regardless of the local urban context or economic power.

This quick-scan desk research is part of the first stage in the development of a practical toolbox of recommendations on how to retrofit existing and design new interchanges taking both human-oriented ("software") and technical ("hardware") aspects of sustainability and low carbon city in general.

It provides a concise overview of theories, technical and design approaches and best practice examples. For every quick-scan desk research chapter included herein we have compiled a list of relevant indicators, strategies, initiatives, actions and methods to develop or achieve them.

The sources list includes work of acknowledged scholars and practitioners, reports of governmental or public transport related organizations, and policy documents.

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Low carbon mobility and urban planning

1.1 Personalized low carbon mobility modes at the station

Walking

The ease of reaching the interchange by walking is a basic indicator of accessibility, though often more attention is paid to the optimal functioning of motorized and rail-bounded transportation systems then on how to access them systems by walking.

Many stations have been conceived primarily as merely an element in the transport network, rather than an integral part of the urban environment. Consequently, local access routes are often neglected, leading to real and perceived inaccessibility of the interchange.

Research by Scott, F. (InterchangeABLE: New design elements to reclaim the transport interchange) defies “Access Ribbons” as a “ typology of carefully designed routes for pedestrians and cyclists, that push out into the neighbourhood to enhance journeys between the interchange and the surrounding area”.

The publication suggests to consider following benefits of the “Access Ribbons’:

- Integrate interchange with surrounding areas
- Creates secure-feeling, safe-routes
- Safety from hazards of heavy traffic
- Provide network of accessible services and info
- Creates retail and service opportunity
- Encourage pedestrian and cycle feeder modes to interchange
- Emphasis on design of specific routes creates clear local identity

Walking as well as other non-motorized modes is a slow-speed movement. Connecting motorized and non-motorized modes of movement presents a challenge in designing an interchange station, because of their different speeds of movement and therefore different planning, design and security requirements.

As stated in their research “Strategies and Tools to Implement Transportation-Efficient Development: A Reference Manual”, the authors point out “that having a direct route available is more important for slower modes of travel (by default non-motorized modes), especially walking”. Walking as a travel mode is always present in the “mobility chain”, and therefore an important aspect not only in transitional spaces (corridors) but also in stationary/sedentary spaces such as parking lots. Poorly designed and badly located parking lots (long walking, several level changes, indirect connection routes) for non-motorized modes (bikes, e-scooters, passengers drop-off zones) create barriers that hamper pedestrian accessibility and limit the use of the station and public transport in general.

Directness of pedestrian routes (fig1, fig 2) and the general quality of walking conditions between different modes of transport is an essential characteristic of a low carbon city. As a general recommendation, pedestrian access and bike access should be positioned at ground level, allowing direct, single levelled connections with the city.

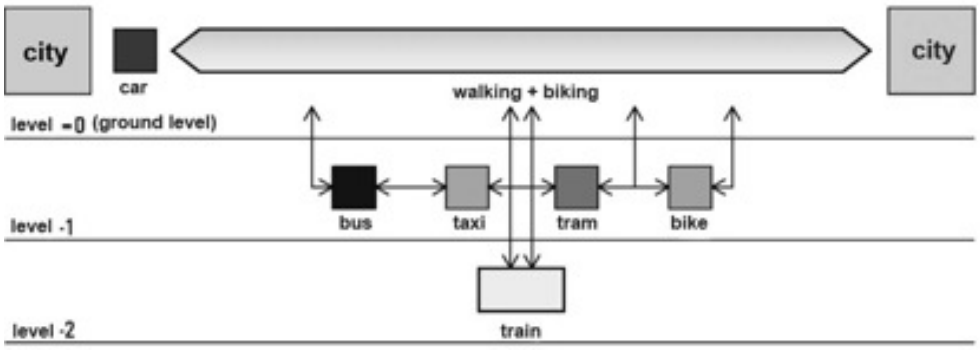


Fig 1: “Locatiesynergie – Een participatieve start van de herontwikkeling van de binnenstedelijke locatie”s, Peek, G.J, PhD Dissertation, TU Delft, 2006.

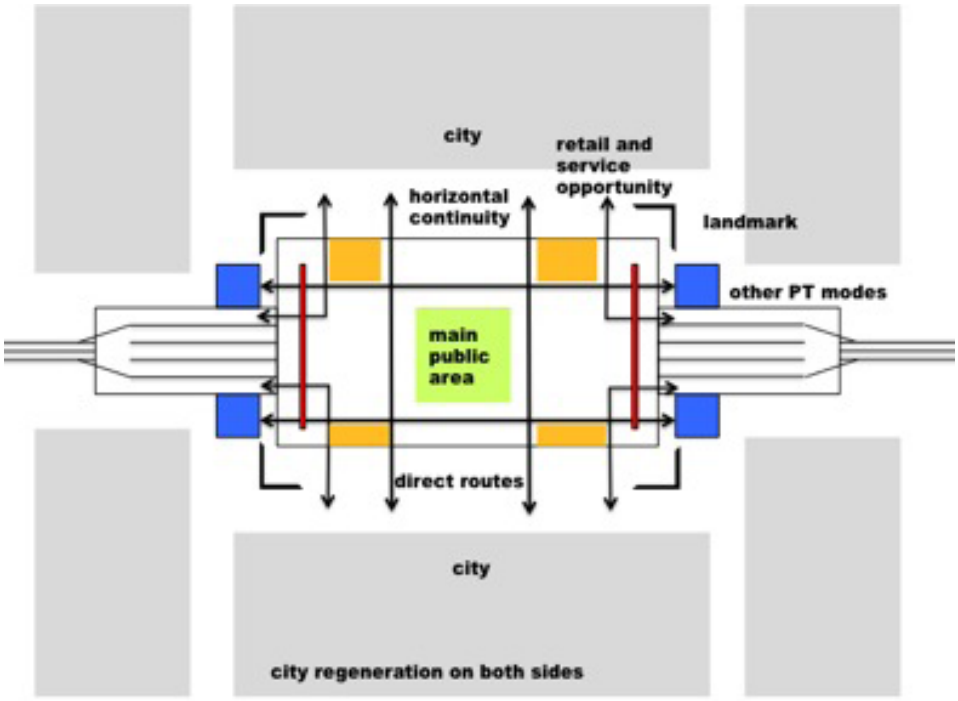


Fig 2: "General model of an interchange and its relation to the city", Toolbox for the design and / or renovation of major interchanges, YDF, 2011

The interconnection of different modes seems to have easy solutions, but its implementation involves complex details of accessibility, urban space management, and information or time-table integration (Burckhart and Blair, 2009: 63). Interconnection with NMT (non-motorized mobility) is more difficult than with motorized transport as it requires different planning and design requirements.

citation from: Integrating BRT Systems with Rickshaws in Developing Cities to Promote Energy Efficient Travel, M. Shafiq-Ur Rahmana, Paul Timms, Francis Montgomery

Accrington Eco Station is a small local station in England, a pilot project and a part of Interreg IVB North West Europe Programme SUStation Research Project.

The project's general survey shows that the majority of station users walk to/from the station. Still, the 47% of those who did not walk indicated they could have walked.	*Accrington Eco Station survey also shows following data on cycling possibilities:* *18% of those who did not cycle indicated they had a bicycle available and could have cycled.*
The main reasons for not walking among those who could have walked were: *too far / long (51%);* *can't be bothered / lazy (16%);* *luggage etc (7%);* *lift available (6%);* *and health (6%).*	*The main reasons for not cycling among those who could have cycled were:* *didn't feel like it (30%);* *short distance (14%);* *luggage etc (12%);* *no secure cycle parking (10%);* *too far or takes too long (9%);* *don't like cycling (6%);* *lack of cycle routes or road safety concern (4%);* *find cycling difficult (4%)*

source: Accrington Eco Rail Station Project Research Findings, Eden Business Analysis

Cycling

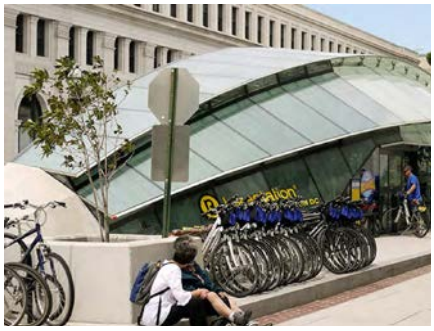
Development of good bike lane access has been at the centre of many low carbon initiatives considering stations and station surroundings. Cycling and bike-and-ride facilities offer a number of environmental and societal benefits over the use of the private car. The environmental benefits include reduction in energy use, air and noise pollution (source: "The bicycle as a feedering mode: experiences from three European countries" Karel Martens ES Lab-Environmental Simulation Laboratory, Porter School of Environmental Studies, Tel Aviv University). The benefits of the cycling

also trigger health, and evidently also financial advantages, as shown in the “Mass Experiment 2012”, a research designed by Professor Niels Egelund, (Centre for Strategic Research in Education, Aarhus University, Denmark) and carried out by researchers from Copenhagen and Aarhus Universities in collaboration with Research Center OPUS and Danish Science Communication. As a part of this trend, in several countries in Europe cycling to work is often encouraged through giving wage benefits. In Belgium, cycling to work is rewarded with 0,20€ / km (in 2013).

Further on, as stated in “The bicycle as a feedering mode: experiences from three European countries”:
The magnitude of these (low-carbon and environmental) benefits will depend on the number and length of the car trips that are being replaced by bike-and-ride. Even in case the bicycle only replaces feedering trips made by car, reductions in air pollution can be substantial given the high pollution levels related to cold starts. In addition to the environmental benefits, replacement of car trips by bike-and-ride could lower congestion levels on specific corridors or on access roads to stations, and could limit the need for bicycle parking lots adjacent to major train stations. Finally, bike-and-ride may strengthen the economic performance of specific types and lines of public transport, as it may attract an additional group of consumers. Taken together, these benefits make a strong case for bike-and-ride (authors: Karel Martens ES Lab-Environmental Simulation Laboratory, Porter School of Environmental Studies, Tel Aviv University).

The same source points out the following: “even in the context of a well-developed bicycle network (such as in the Netherlands), these networks do not always encompass bicycle lanes along main access roads to rail and bus stations. Less attention has been paid to specific facilities that increase the attractiveness of the combined use of bicycle and public transport. Traditionally, train stations have been equipped with guarded bicycle parking, but lack of investment during the 1970s and 1980s resulted in problems regarding the quality, quantity and accessibility of many of these facilities”. Furthermore, “ Generally, bicycles were seen as competitors of buses, trams and metro lines. Bicycle parking facilities were usually only provided following an apparent demand in terms of parked bicycles at public transport stops. The lack of systematic attention is reflected in the number of bus, tram and metro stops that are equipped with bicycle parking facilities. Estimates show that 10–20% of all stops have dedicated parking facilities (Van Uum et al., 1995). (source: “The bicycle as a feedering mode: experiences from three European countries”, Karel Martens ES Lab-Environmental Simulation Laboratory, Porter School of Environmental Studies, Tel Aviv University).

Fortunately, this disinvestment trend is gradually reversing, as railway operators start to consider cycling as part of the travel chain. Currently, major if not all railway operators in Europe invest in the development of well-lit, maintained and guarded bicycle parks, often accompanied with bike spare parts and repair shops.



Low carbon motorized mobility

Besides stimulating more clean-fuel public transport vehicle fleets, and promoting the use of green fuel / hybrid private cars, low carbon city transit policies put clear emphasis on encouraging other carbon-minimal alternatives and concepts over private cars, such as electric scooters, electric bikes or sharing and mobility-on-demand systems.

These new concepts have still to find their place and space within the domain of the station. As noted in the previous research actions by Yellow design Foundation ("Toolbox for the design and / or renovation of major interchanges" UIC publications) many existing interchanges in the heart of large urban centres cope with finding quality space to promote this new concept to users. Traditional layouts of stations and station surroundings leave little or no space to add new functions. The chapter 'land-use' of this research will focus on alternatives to overcome this problem.

Drin Bus Genoa, Italy:

A classic example of "demand responsive transport" – in this case, a flexible bus service that connects the hilly, low-density areas of Genoa through an operational model of "many to many" pickup and drop-off points. A rider can reserve the bus up to 30 minutes prior to his or her desired departure time via telephone, or catch it "on the road" if the bus has space

Source: "Connected Sustainable Cities" from William J. Mitchell & Federico Casalegno, MIT Mobile Experience Lab

1.2 Station embedded in the city

Moving from Transit Oriented Development to Transit Efficient Development

TOD (Transit Oriented Development) planning theory and practice emerged as a reaction to the intense development of car-dependent, sprawled and mono-functional urban and suburban areas. In both the USA and Europe, the concept has been used as a starting point to discover public transport as a catalyst for revitalisation of urban neighbourhoods, an instrument that will bring new investments to the community, and enhance its sustainability through mixed use of spaces. The public transport station was re-discovered, and no longer seen as just a piece of infrastructure, but as an urban public space, a heterotopia, a vital focal point for the community and beyond.

TOD integrates transportation in order to achieve a number of different objectives. “By facilitating more public transportation and more frequent use of public transportation, TOD can reduce dependence on fossil fuels, lower passenger transportation costs, promote walking and health, ease traffic congestion and improve environmental quality” (“Strategies and Tools to Implement Transportation-Efficient Development: A Reference Manual”). The same source, however, also points out that “thus far, many projects marketed as TODs are not fundamentally different from traditional residential suburban developments: they are not well-integrated with the station or the surrounding community, they include excessive parking, and they are neither mixed-use nor mixed-income.”

Recent developments in smart city theories and concepts, low carbon policies and general public awareness about the need for paradigm shift, (in terms of the way we move) are transforming the TOD concept to TED, or Transport Efficient Development. This overly proves that mobility and urban planning must go hand in hand.

TED and transport efficiency in general can be defined as “having a choice of easily accessible travel modes, lowering the need for Single-Occupant Vehicle (SOV) travel, and increasing opportunities for para-transit, transit, and non-motorized travel” (“Strategies and Tools to Implement Transportation-Efficient Development: A Reference Manual” Anne Vernez-Moudon, Professor, Matthew Cail, Nicolas Pergakes, Colin Forsyth, Lora Lillard, Research Assistants, Urban Form Lab, Department of Urban Design and Planning, University of Washington, Seattle, Washington and Washington State Transportation Center, September 2003)

It also implies more intensive use of existing infrastructure, redefinition of street profiles and public spaces. For stations and station surroundings this pushes for more attention to managing the flows between different modi and taking into account user patterns, their aspirations and their needs.

An important TED indicator is the quality and density of development within 500 meters of transit stations. (fig 4,6)The 500 m benchmark is often used as a bottom line of walkability ("Benchmark of Asian Public transport Interchanges", UIC-Yellow design Foundation 2011). This indicator is also used to compare the developments within three major European interchanges (Toolbox for the design and / or renovation of major interchanges, UIC, Yellow design Foundation 2010) (fig. 5) concluding that not only the variety of functions, but the quality and size of public spaces (such as squares and street profiles) are equally important.

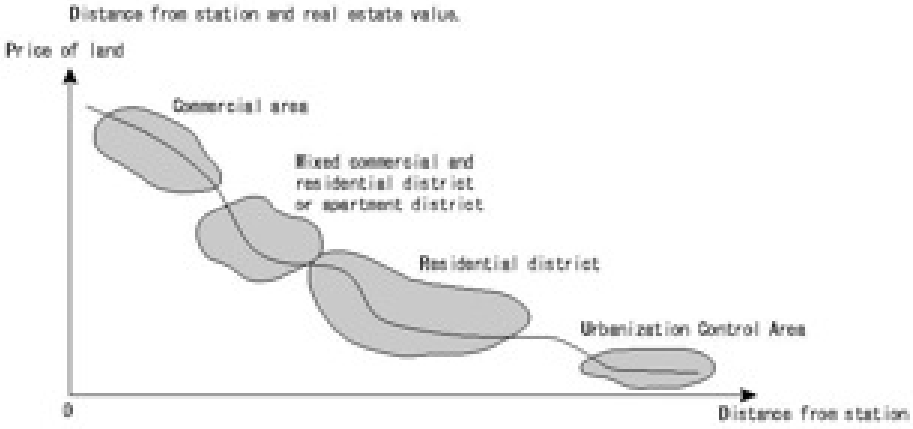


Fig 4: "Distance from station and real estate value", Kogakuin University, Tokyo, Department of Architecture, in "Benchmark of Asian public transport interchanges", YdF, 2011

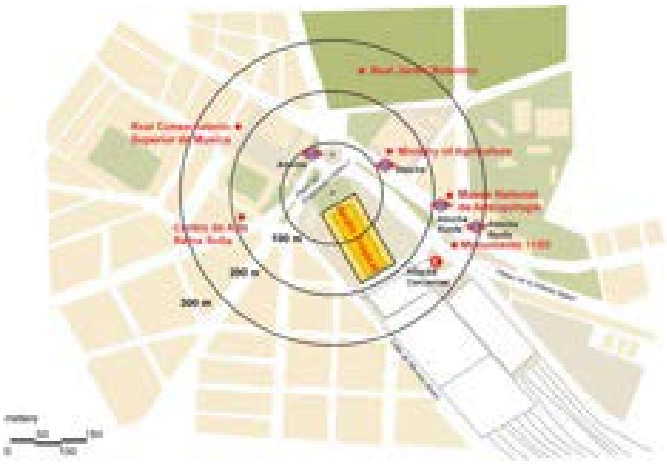


Fig 5: “Walking distances – comparison of several European station surroundings”, Toolbox for the design and / or renovation of major interchanges, YDF, 2011

LOS	Transfer time	The weighted average distance
A	Within 1 min.	Under 60m
B	1-2 min.	Under 60-120m
C	2-3 min.	Under 120-180m
D	3-4 min.	Under 180-240m
E	4-5min.	Under 240-300m
F	Above 5 min.	Above 300m

* walking velocity is assumed as 1.0m/sec

Fig 6: LOS or the Level of Service (A stands for highest level, F stands for lowest level) correlated to the transfer time getting into and out of the transport vehicle. Source “Study on the foreign / Korean Railway Station Transfer System and Implications) Kim KwangMo, Park YongGul, Kim JinHo, Choi SungPi, Seoul National University and Korea Railroad Research Institute

Station as a community hub

As cited in the research of Scott, F. (InterchangeABLE: New design elements to reclaim the transport interchange), “Transport hubs are often situated in public spaces of low quality. Such spaces are busy and potentially vibrant, but too often they are desolate and characterless, failing to respond to their social and cultural context”.

Depending on the local context, different strategies are needed to address this problem. In the context of the developing world, the difficulty lies in balancing land-use policies, existing social and cultural perceptions of public space, and urgency to develop sustainable urban mobility schemes within limited budgets. As the authors of the “Radical standard for the implementation of Spatial Justice in urban planning and design” (Institut fur Stadtebau – Technische Universitat Braunschweig, Johannes Fiedler, Melanie Humann, Manuela Kolke) mention, the social dimension of mobility in the developing world is equally important as economically needed. In their research they also conclude that accessibility is the key to an ideal model of socially aware mobility planning: “Ownership of the car is not required to get home after an event, that children can get to school or use public transport by themselves already at an early age, that there is no need for humiliating walkways or delays in a public space when using a job centre or a social base. People who rely on public support because of their status (as migrants) must not be expected to accept higher levels of inconvenience to enjoy public benefits than the members of the local population.”

If we want to position the station as a “heterotopia and community hub”, a place for the benefit and enrichment of the surrounding neighbourhood, we should first think of making it an accessible public space, with strong local identity. In the developing world, it should also be a place of “creating opportunities”, through varied use of surrounding space and programming. Next to commuting, users should be able to find a certain service, job and education possibilities, to contribute to a local market, but also to be able to find space for meeting and leisure.

Station’s infrastructure and its impact on the surroundings

Noise and vibrations

Whether positioned is in the urban core or at the periphery of the city, a multimodal station always creates great impact on its surroundings. The most evident physical impact station’s infrastructure has on a surrounding is the creation of a barrier – urban space is usually divided in a space “in front” and “behind” the station, or in case of terminal stations, in space “in front” and “operational” space for the trains, busses, trams and other transportation modi.

Besides creating barriers, stations also have great environmental impact. According to Arnd Batzner, (PhD candidate and researcher at the University of St.Gallen, Institute for Systemic Management and Public Governance) “Among the most important are noise and vibrations, coming from different transport modi and operations. While vibration emissions from a transit interchange will generally originate from technical operation, for a holistic assessment of noise emissions it is key to differentiate between two basic sources of noise:

• Technical noise originating from transit operation
• Ambient noise originating from users of the transit interchange”

Thus, Batzner suggests to consider “four clearly delimited topics of noise and vibration emission:

1. Noise Emissions from Vehicles / Technical Operation
2. Vibration Emissions from Vehicles / Technical Operation
3. Noise Emissions from Users
4. Incorporating Noise and Vibration Emissions into an Environmental Impact Consideration”

1. Noise Emissions from Vehicles / Technical Operation

• Building typology of transit interchange: Open / Semi-Open / Fully Enclosed

Generally, upgrading measures of transit interchanges will lead from open forms, i.e. in an urban square, to semi-closed ones (i.e. use of ground floor of an elevated building) to fully enclosed ones, where the full operation take place inside an over- or underground structure.

It is important to note that both user comfort (protection from heat, rain or snow, possible air conditioning of the passenger’s area) and operational reliability (less risk of disorderly operation) will benefit from a subsequent move towards fully enclosed structures, while noise emissions tend to decrease. Globally, with an upgrading of the neighboring urban environments, noise emission from a transit interchange will increasingly be met with negative perception.

• Vehicle Types in operation: New / Older / Mixed

The second important area to be considered is the vehicle type operating in the transit interchange considered: For rail vehicles, it is especially breaking noise that has been identified as primary source of aural discomfort for the environment. While on rail vehicles that are new or less than ten years of age, breaking noise has generally been eliminated through manufacturing

changes in the breaking systems, the issue is more complex for older vehicles: Research from Europe and the US shows that the possibilities of retro-fitting older rail vehicles with low-noise breaking components is limited. Thus, only new generations of vehicles will substantially improve the situation. It is to be considered that the lifetime of a rail vehicle will be typically 40 years, with possible extensions. This is to be considered when designing or re-designing transit interchanges.

For road vehicles, investment cycles are much shorter. Transit buses can be assumed to have an average operational time of 10 years. Current Euro-5 or Euro-6 vehicles are significantly less noisy than older types. The situation will be different for transit systems relying on second-hand vehicles that have retired from service e.g. in Europe, or on vehicles of an intentionally low-cost design (e.g. low-cost types from China, Brazil) that do not meet the latest standards.

2. Vibration Emissions from Vehicles / Technical Operation

Generally, vibration issues are a major issue with rail vehicle operation only. To be considered here are two major points:

- Vehicle Design: Older vehicles in operation will generally have more non-suspended compounds than newer ones, resulting in significantly higher levels of vibration generated. As discussed in section 1, the replacement cycle of vehicles will be the key factor addressing the problem.
- Track Design: Latest track designs include damping elements that largely reduce or eliminate vibration from rail vehicle operation. In general, an upgrade of older track is only possible by redesigning and fully replacing rail tracks, which can result in high costs and longer operational disruptions. For this reason, an upgrade will generally only be reasonable when a transit interchange is fully rebuilt.

3. Noise Emissions from Users

Increasingly, user noise originating from transit interchanges has become a topic of controversial urban policy discussions: Since transit interchanges attract large numbers of passengers, secondary and tertiary commercial activity will be attracted to the interchange and it's neighborhood. In general, this upgrades safety in the surrounding area, generates profits for the transit system and is thus a welcome effect.

With the move towards 24-hour-operation and more mobile societies, noise emissions especially from commercial operations in the environment (shops, delis, restaurants, bars) have become a source of controversy since they negatively affect the comfort e.g. of nearby residents.
Ultimately, balancing these effects and finding a locally adapted solution

for each individual case refers to political decision-making: Is a transit interchange desirable to function as a commercial hub, or shall it's function be voluntarily restricted to a transportation function? This question can only be answered considering the entire design of the interchange within it's urban environment, since a large number of other issues are concerned.

4. Incorporating Noise and Vibration Emissions into an Environmental Impact Consideration

It is important to note that any planning of dealing with noise or vibration emissions will have to be fully integrated into the planning of

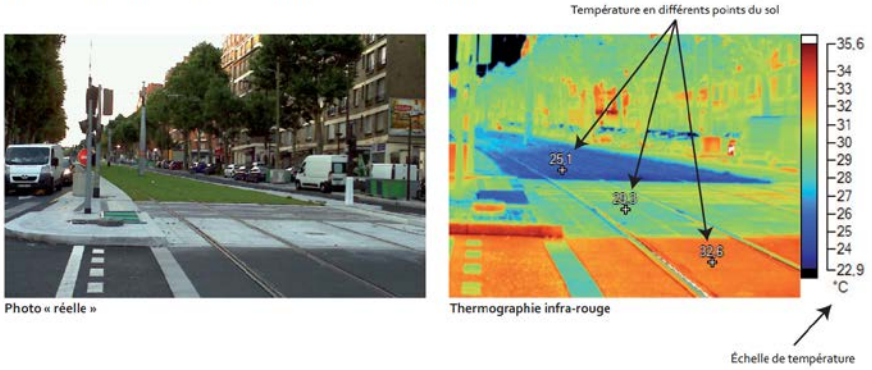
- the medium-term evolution of a transit system
- the projected passenger flux growth rates in a specific interchange
- the medium- to long-term evolution of the urban environment
- socially acceptable types and levels of nuisance

A zero-emission, benefit-only transit interchange is not conceivable, though the opportunity to build or re-build a facility from scratch"

Urban heat island effect

Multimodal stations are often located in urban landscapes full of asphalt, metal and dark buildings, which easily absorb more energy from sunlight than natural landscapes. This excessive absorption during the day, and its release at nighttime cause the so-called Urban Heat Island (UHI) effect. Consequences of this effect are that cities experience significantly warmer temperatures than surrounding regions. On a smaller scale, it means that certain areas within the city are significantly warmer than others. Conventional approaches to regulate microclimate and diminish the side-effects of UHI's within the buildings is the increased use of air-conditioning, which in turn uses a lot of (mostly fossil fuel-based) energy which again causes increased CO2 levels.

FIGURE 2 – EXEMPLES DE CLICHÉS PRIS SUR L'AMÉNAGEMENT DU TRAMWAY T3, BOULEVARD MORTIER



Preventing or diminishing the urban heat island effect has become one of the main issues of the so-called urban resilience, or the capability of an urban area to deal with climate changes and negative impacts of urbanization. Another important issue in the urban resilience is the water management in the urban areas, which is discussed further in this desk research report.

Considering that stations and station yards usually comprise of large bundle of rail and road infrastructure, their role in causing the UHI effect on the surroundings should be examined whether by adaptation of an existing station, or by the planning of new ones. There are fewer and fewer surfaces with natural landscaping left around stations, preventing water to evaporate, which is a main factor in cooling or maintaining a constant microclimate during the day.

Another feature typical for the station surroundings and their infrastructure is the fact that ground is most of the times “sealed”, whether due to use of asphalt surfaces or high densities. When the ground is “sealed”, evaporation and water storage is greatly reduced, amplifying the UHI effect. Also, sealed surfaces mean that elaborate and (relatively) expensive measures need to be taken in order to facilitate rainwater run-off.

Within station surroundings, especially vulnerable station functions are large car parking lots, bus terminals, or large station buildings. Also the adjoining grid of streets and lack of green landscaped public spaces can increase the UHI effects. The amount of asphalt and concrete coming from infrastructure, in combination with large footprint buildings are sometimes unavoidable in the historic city centers, where UHI effects can be diminished through careful adaptation.

Due to the bundling of infrastructure, station surroundings suffer extra burden from the so-called “waste heat” from train, bus and car operations. This of course, has a cumulative effect on the UHI phenomenon, contributing to the deterioration of the public space quality.

From a planning and design point of view, introducing and maintaining near-natural surfaces in the infrastructure and public spaces in the surroundings can offer a solution. Near-natural surfaces are sorts of pavements with more porous or composite structure (such as e.g. Ecogrid) that allow easier water infiltration, or can be filled with grass or natural ground. The use of near-natural surfaces is not always possible, especially in areas with heavy (motorized) traffic, where smooth and very compact (sealed) surfaces are required. But on non-permanent parking lots, public areas such as station squares, bicycle parking’s etc, these materials can be applied. Also, reducing the use of tightly interlocked stones, and pavements in open public areas can support the natural process of water circulation and evaporation, which reduces the UHI effects on a micro level.

1.3 Land-use and the interchange

Efficient travel behaviour is positively associated with effective land-use in the station surroundings, such as dense residential areas, availability of work space, and a mix of complementary functions, such as retail ,education, health, culture, etc. (“Equitable Development Toolkit, Transit Oriented Development”, PolicyLink Institute).

The following issues (“Strategies and Tools to Implement Transportation-Efficient Development: A Reference Manual”) are important aspects concerning land-use, making the interchange more attractive, and therefore more relevant in a low carbon city context:

- surrounding block morphology
- parking solutions (stationary spaces for both motorized and non-motorized spaces)
- re-use of vacant buildings (within station yard of direct vicinity)
- street network

In this context, it is important to develop an in-depth understanding of how PT infrastructure influences urban space, what are its negative triggers on land-use, and how can they be reduced. Access roads to the station (sometimes overloaded with public transport corridors, such as Bus Rapid Transit reserved lanes) and railway tracks (all combined) represent strong barriers that cut through urban space, leaving pockets of neglected lots behind. As such they cut off the neighbourhood from the remaining city dynamics and can, if no further action is taken, possibly become urban no-go zones. Stations who don’t respond to the “barrier” effect are often perceived as an “interruption” rather then a cohesive factor.

Intensity of land-use

In theory (Nodes and Places: Complexities of Railway Station Redevelopment, Bertolini, L), a “node-place” model provides an analytical framework to penetrate the dynamics of station area development. The underlying idea is that improving transport (mobility) offer in a location, will, create conditions that favour further intensification and diversification of land-uses there.

But this is only one aspect of the land-use around stations. Its dynamics depend on the local conditions, as the comparison between several European and Asian stations shows (“Benchmark of Asian Public transport Interchanges”, UIC YDF, 2011), (fig 7, 8) intensifying is not always “the rule”, and is strongly dependent on the urban context and the development of public transport network in general.

Fig 7: "Station footprints – comparison of several European interchanges", Toolbox for the design and / or renovation of major interchanges, YDF, 2011

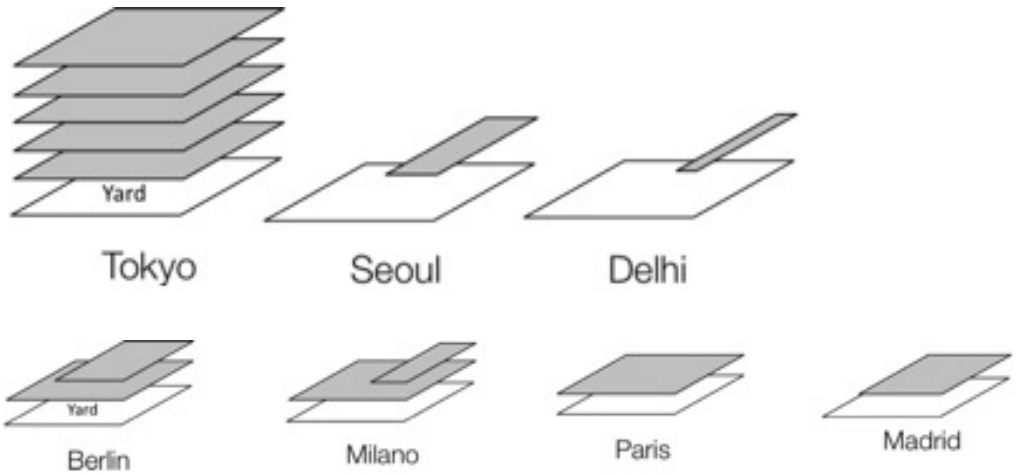


Fig 8: "Intensity of land use of the station yard – comparison between European and Asian interchanges", Toolbox for the design and / or renovation of major interchanges, YDF, 2011

Land-use, urban topography and alternative sustainable mobility

According to the UN predictions, (source) “by 2050 almost two-thirds of the world population will live in metropolitan area”. Of these, “more than half will be urban dwellers, their homes being self-built shelters erected illegally, resulting from poor or absent urban planning policies. An important, if not dominating part of urban residential areas will thus be informal character. “ (source: *Arnd Bätzner, “Formalization Strategies for Informal Transport through Elevated Connectors: Comparative Learnings from Developing and Developed Environments Re-Defining Urban Accessibility in the Third Dimension through Urban Cable Cars, People Movers and Elevated Walkways University of St.Gallen, Institute for Systemic Management and Public Governance, 2013*)

Witnessing the already large-and-growing scale of informal settlements in East Africa, and the pressure it brings to the city streets and urban transport system, we can conclude that efforts directed to find optimal, low-cost solutions to improve this situation deserve special attention. As Batzner further notices,”the lack of access to efficient, structured forms of mobility is a problem encountered in informal settlement areas around the world. Such deficits become even more challenging when concerning densely populated urban areas with steep, thus difficult topography” As we can learn from Latin America’s examples, (and also from high-density, difficult topology of Hong Kong and high-density and flat topology of Singapore) introducing cable-car systems and people-mover systems suitable for the local conditions, can facilitate better personal mobility. Looking from the point of view of transforming the existent informal public transport systems, Batzner also notices that cable car systems in Latin America are “ largely replacing or re-assigning informal transportation such as shared vans that had previously been the primary mode of motorized transport in these areas”. To what extent these systems influence the land-use patterns in their vicinity, and therefore the whole local economy, requires further research.

The relation between land-use, topography and sustainable mobility has another dimension in Africa, where most of the growing urban areas are lying in the high planes, large river deltas, or flat coastlines. In these cases, the challenge is how to establish an efficient network of open spaces (both public and traffic corridors) in relatively flat, but extremely densely built areas.

How can sustainable modes of mobility be promoted and implemented in the land-use policies of these cities? A good framework for this question is given by Dr. Joan Clos, (Executive Director, UN-HABITAT) in his speech at UNACLA meeting (UN Advisory Comitte on Local Authorities, drafts on regular meeting 20 April 2011) where he presents the disparity in the

percentage of land dedicated to street space in 19th century Manhattan, and the Kibera (Nairobi) slum of the 20th century: "(Manhattan was) Planned in 1811 for the use of horses and carts - 36% of the whole urban area was designated as street space. He juxtaposed this against Kibera slum in Nairobi where street space accounts for just 2.7%.", Further he also " underlined the importance of achieving both economies of urbanization and agglomeration – a situation which necessitates a fine balance between streets and density. He implied that a city requires a minimum of 30% designated street space and approximately 12,000-15,000 inhabitants per km^2."

Human programming and physical structure

2.1 Human programming

Following the theory of hierarchy of cities as defined by Saskia Sassen in her work "The Global City", YdF has transposed some of the Sassen's principles to the aspects of human engineering and ergonomics at the interchange station. Station users have their specific aspirations, expectations and needs regarding intuitive use and understanding of the stations' space, and these needs are independent of the size or complexity of the station. Furthermore it may be assumed that the afore mentioned needs are theoretically shared by the vast majority of passengers. In practice however, in the passengers' minds, their actual pertinence will depend on whether they travel by metro (train frequency of 90sec), by commuter train (train frequency of 10min) or by High Speed train (train frequency of 60min).

However, the stations operator's answer to these needs is highly depended on the hierarchical position of the station in terms of operational and nodal volume – e.g. the answer to the needs depends whether the interchange welcomes the passengers of 2 trains per day or passengers of 60 trains and 150 busses per day.

To be able to define recommendations on how to overcome frequently occurring spatial discrepancy between satisfying the universal needs of the passengers and satisfying the needs to smoothly operate transportation systems, we will closer look to the issues of human programming at the station.

In its "Best Practice Guidelines, Quick Reference Guide" Transport for London defines two groups of users, commuters (frequent users) and other passengers (tourists, leisure travellers and occasional visitors)

In the base of this categorisation lies the division based on the temporal character of travelling (frequently or occasionally) which defines terms of the use of the station space – short time, but recurrent use (commuters) or more long time, occasional use (tourists, visitors).

Both groups demand: according to the “Best Practice Guidelines, Quick Reference Guide” TfL
- full accessibility, seamless travel between different modi
- simple and intuitive way-finding,
- good waiting areas and basic amenities
- reliability and real time information
- safety
- convenience shopping and catering, combined with so-called “comparison” shopping

Regardless of their expected waiting time and travel destination, all users have the same needs when it comes to the quality of the space they are waiting, moving or doing some other activities.
Human beings develop their behaviour based on their understanding of the space, experience and sensual input. Our senses tell us if a space is well maintained, hence possibly well managed and taken care of.

In the following chapters we will look closely to the most important environmental and microclimate factors of the stations’ public space, that have great impact on the personal comfort, perception and behaviour of the station users. We will first shortly summarize some theoretical sources and aspects of human physical comfort, and then also present technical tools to facilitate and manage these needs in the station’s spaces, in the chapter “Building envelope”.

Sensing and physical comfort in the stations public space

- thermal comfort

The way thermal sensations and perception of heat of coolness influence the behaviour of the passengers and its use of public spaces of the station is of utmost importance in defying guidance on how to provide right design solutions. In “Life Between buildings: Using Public Space” Jan Gehl underlines the influence of microclimate on outdoor activities and substantiates it by simply counting people sitting on sunny and shady benches. Gehl showed that local sunny or shady conditions significantly impact the desire of people to either stay or leave.

In the station environment, most of the attention goes to the inside thermal comfort, and less to the outside thermal comfort, while it is the outside comfort that is as important for the complete “mobility trajectory” (arriving - being at the station - boarding a vehicle) as the inside one, Inside environments are also easy to manage using technical means, (and by very large stations this is almost always a necessity) which are not always sustainable. If we want to stimulate the use of sustainable mobility in the low carbon cities, we have to pay more attention to both inside and outside environmental aspects of station and its surroundings.

Air temperature and relative humidity are main technical indicators of thermal comfort conditions.
Local climate conditions in combination with the built structure of the immediate surrounding of the station and the station itself represent a very complex set of elements influencing the sense of well-being and health of the passengers. Air temperature has the most direct effect on thermal comfort. In the indoor environment. the perceived temperature is influenced by the choice of materials, their colouring, height of ceilings, natural or artificial ventilation possible air-conditioning, solar heat gain, other heat sources such as light, electrical equipment, computers and water heaters, and humidity. The temperature level at which people feel comfortable will depend on activity levels, age and natural body temperature which will vary from individual to individual, and on seasonal temperatures (“Guidance Notes for the Management of Indoor Air Quality in Offices and Public Places”, The Government of Hong Kong).

The humidity levels, and the combination of humidity and temperature also influence feeling of comfort. This combination directly influences the physiology of the human body, by affecting its abilities to regulate body heat through perspiration. Another important ingredient in the complex system of perceiving environmental comfort is the amount of air movement round the human body.
The aerial movement is largely dependent on the general climate characteristics, but in the built environment it can be further enhanced (or diminished) by the characteristics of built environment. In the station outdoors, high buildings can often intensify natural air movement in the public space by forming unpleasant “wind tunnels” and help disperse air pollutants. Indoors, air movement is most of the time artificially regulated (through general air-conditioning) which requires good maintenance of the ventilation systems. Blocked or unbalanced ventilation systems, or too low pressure levels in ventilation ducts may restrict air movement, producing a “stuffy” atmosphere which makes occupants feel uncomfortable (“Guidance Notes for the Management of Indoor Air Quality in Offices and Public Places”, The Government of Hong Kong).

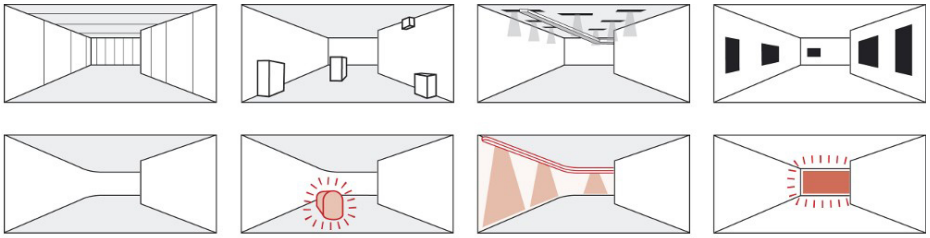
- visual comfort

  Visual comfort and the quality of sight lines affect the perceived security of users as well as objective security.

Light can be considered an essential component of visual comfort within the more complex environment of the interchange. Even under optimal sight conditions it is of key importance operators/authorities set clear standards for functional signage and branding of retail premises.

For example, next to a good balance between functional signage and commercial branding in the station, poorly designed or wrongly positioned visual signage can be fatal for proper functioning and access to the interchange. The design of information boards and other visual signage (often integrated in “light boxes”) is directly responsible for communicating and providing information to the passengers (“Benchmark of Asian Public transport Interchanges”, YDF).

It needs to be considered that energy-efficiency measures of applying strong white-light LED illumination and highly reflective flooring and walling materials in the interiors and corridors can have a negative impact on passengers, creating sterile, unpleasant interiors (“Benchmark of Asian Public transport Interchanges”, YDF).



- audio comfort

Audio comfort is often connected with sound quality in the station environment. In its broader sense, sound quality can be defined as the indicator of relationships between the sounds, space and social practices. Therefore, sound quality of a certain space involves a cross analysis between space, acoustics, and people's behaviours ("Sound quality in rail station : users' perceptions and predictability", Rémy, Nicolas). This research points out that the same formal "acoustic parameters" can create a different sound quality perception by users. Another source elaborates further on the significance of individual perception of the audio comfort: "However, considerable differences have been found between the subjective evaluation of the sound level and the acoustic comfort evaluation: people tend to show more tolerance in terms of acoustic comfort evaluation. The background sound level has been found to be an important index in evaluating soundscape in urban open public spaces – a lower background level tends to make people feel quieter. Analyses of individual sound elements show that the acoustic comfort evaluation is greatly affected by the sound source type – introducing a pleasant sound can considerably improve the acoustic comfort, even when its sound level is rather high.
(W. Yang, J. Kang, Acoustic comfort evaluation in urban open public spaces, Applied Acoustics, Volume 66, Issue 2, February 2005, Pages 211-229, ISSN 0003-682X, 10.1016/j.apacoust.2004.07.011.)

Managing noise levels in the station environment is more easy within the enclosed station environment, than in its outdoor public space. Outdoor station environments and waiting areas often belong to complex urban fabric and activities, which are harder to regulate. Reducing noise levels, as a measure to increase comfort outdoors, (and in the public space) has been the main focus of different environmental regulations for quite some time now. The solutions to noise reductions are often costly, and sometimes aggravating urban landscape and visual comfort. According to research carried at Sheffield University, (J. Kang, Noise Management: Soundscape Approach, In: Editor-in-Chief: Jerome O. Nriagu, Editor(s)-in-Chief, Encyclopedia of Environmental Health, Elsevier, Burlington, 2011)

so-called soundscaping can offer more sustainable solutions. “Soundscape approach, different from noise control engineering, is about the relationship between the ear, human beings, sound environments, and society. It represents a timely paradigm shift in that it considers environmental sounds as a ‘resource’ rather than a ‘waste.’

Operational noise control

Technical improvements of the rail tracks, asphalt layers and vehicles are crucial for the improvement of the comfort in the immediate public space of the stations.

As stated before, breaking noise of rail operations is the most intensive source of noise at the platforms and other waiting areas, the peak noise being the arrival at the station and braking. (The Black Friars metro station in London is one of the first stations using new type of rails, the SilentTrack, in order to minimize this noise) “Idling” trains (running engines, but not moving) are also a possible source of operational noise at the platforms, their impact depending of the idle time of the train.

Although not coming from the railway operations, noise from CHP installations can also have an impact, if they are not properly acoustically isolated.

The adaptive design of the platform furniture can contribute to better aural comfort at the platforms, responding to noise presence in general, and not to particular noise sources. Among the examples that can have influence on diminishing the influence of the noise are larger benches with higher back towards the noise sources. The position of information panels at the station can also play the role of “noise screens”.

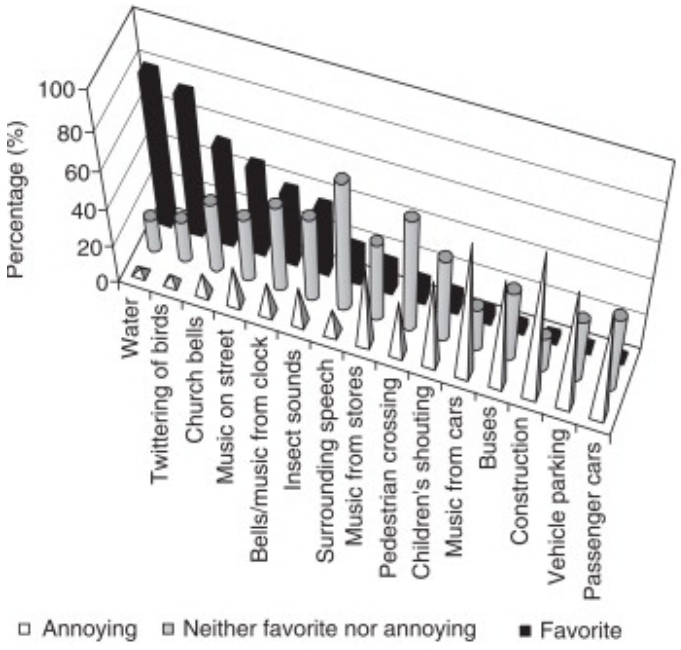


Fig 8a: "Classification of typical sounds in urban open spaces, based on a survey in Sheffield", J. Kang, Noise Management: Soundscape Approach, In:, Encyclopedia of Environmental Health, Elsevier, Burlington, 2011

Simple and intuitive way-finding

The first and foremost objective of an interchange is to offer efficient and effective access to transportation. Although technology offers a variety of possibilities to provide accurate and relevant access information as well as about the spatial configuration of the station and its travel services, simple and intuitive way-finding remains a difficult task to accomplish. The intricate multi-levelled piling up of infrastructure at interchanges, as well as putting its functional requirements before human needs, has created unattractive stations in the past. These experiences are partly diminished in the newly built interchange concepts, but still there are persistent obstacles to simple and intuitive way-finding.

As noted in "InterchangeABLE: New design elements to reclaim the transport interchange", transport operators often use "different system for displaying travel information, and do not co-ordinate their design or layout. There is a piecemeal accumulation of conflicting signals, resulting in clutter and confusion. To make interchanges visually more appealing and to promote the ease of travelling, layers of information need to be coherently arranged according to the station information strategy, in which transport information should have priority over commercial ones".

Creating coherent scenery is essential for intuitive wayfinding at the station and station surroundings. In his “Image of the City”, Kevin Lynch states that often the urban “environment is still not being treated as a whole, but rather as a collection of parts (the sequences) arranged so as not to interfere with each other.” which is very much true for cities planned on modernistic, functional zoning principles.

Next to creating a coherent scenery, on of the key issues of intuitive way-finding is to allow users to orientate according to simple (usually emotionally rich) visual clues in the environment. In the case of large station environments, it should allow users to navigate through different parts of the station, without having to “understand” the whole system first.

According to UIC-International Railway Union’s “Measures to facilitate travel by rail” (Code leaflet No. 413,10th edition, January 2008) the “different items of information (such as indication of carrier, train category, route, destination station, departure time, train formation, etc.) should always be shown in the same place and using the same layout and colours as far as technically possible. Information is more easily recognized and followed if:
- the same object or the same direction is always shown in uniform manner
- the lighting is adequate at all times
- it is not jeopardized by its environment “

These simple, universal principles of information provision should be applied to all other transport modalities. But often these standards are not equally applied to all present modalities at the station, making some of the modalities "underprivileged" and therefore discouraging to users. The same UIC publication suggests the following list of minimum information that should be presented to the user:

" Information on the following points should always be supplied as a minimum:
- train services (information bureaus, paper timetables, departure boards, etc.)
- the different facilities and installations available and where they are to be found – especially in large, complex stations where it is not easy to find one's way (station plans, signposting)
- place of arrival and departure of the train or coach that the passenger is concerned with (notice boards, platform indicators, train formation diagrams, marking of platform areas, visual display screens for instant information, etc.)
- any incidents and accidents that may arise, strikes, delays, replacement services, change of departure platforms and /or train formation, guaranteed services, etc."

Safety and (perceived) security

The safety standards an interchange must meet are generally well documented and regulated even though under constant evolution due to changing external environments, increased levels of passenger use and higher levels of risk awareness.

The security of an interchange at it is perceived by users is a major hurdle to pass if we want to increase the use, hence the market share of public transport. From past research (YDF 'link between design and security', Security by design, 2008) we have been able to conclude perceived (in) security is independent of gender, race, religion, intellect social status, it must be considered an element to address. Perceived security results both from objective or measureable elements and from emotional triggers. (fig.9)

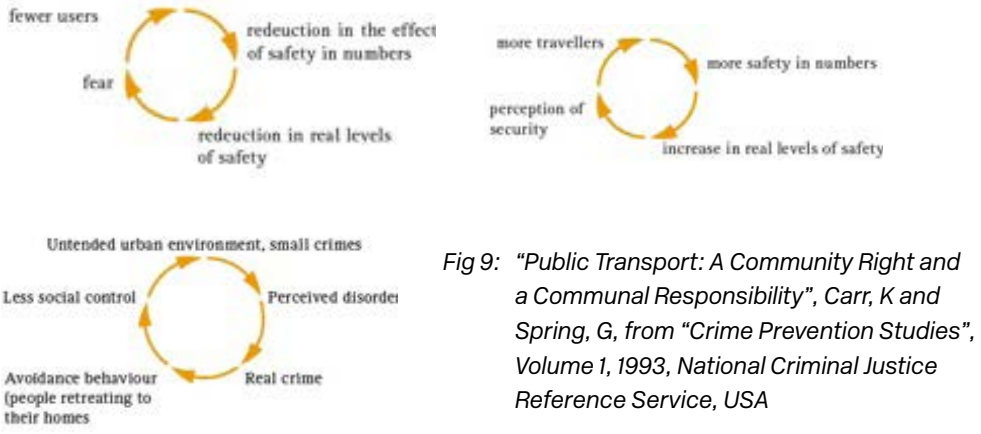


Fig 9: "Public Transport: A Community Right and a Communal Responsibility", Carr, K and Spring, G, from "Crime Prevention Studies", Volume 1, 1993, National Criminal Justice Reference Service, USA

Trust, as a basic social virtue of public transport interchanges should not be replaced by control as it may lead to exclusion of certain groups of interchange users. It should not be forgotten that public transport interchange, by definition, is public space, thus freely accessible to everyone (Hajer & Reijndorp, 2001). The most effective control is presence of people, as acknowledged by urban activist Jane Jacobs: “The first thing to understand is that the public peace – the sidewalk and street peace – of cities is not kept primarily by the police, necessary as police are. It is kept primarily by an intricate, almost unconscious, network of voluntary controls and standards among the people themselves, and enforced by the people themselves.” (“The Life and Death of Great American Cities”, Jane Jacobs, 1961, p.32)

The general lay-out and atmosphere of an interchange can have an important impact on possible levels of of discomfort, unease or feelings of threat

The improvement of perceived security can be tackled at 3 different levels of intervention. (cfr SPIN-UP by YDF 2008):

- infrastructure
- equipment
- daily operations

What is SPIN-UP?

SPIN-UP is a methodology that assesses and improves the quality of public space and public transport space.

In early 2004 Yellow design Foundation started defining the research project that would endeavour to explore the mechanism and boundaries of perceived security as well as the link between perceived security and design in transit zones of inter-modal stations of urban public transport. This ultimately resulted in the conception and development of the SPIN-UP (Security Perception in Inter-modal Stations for Urban Public transport) methodology.

Our major concern was that very often, only engineers and security personnel were invited to define the quality of a public space in terms of perceived security without considering neither the human and social tissue surrounding the station, nor consulting non-technical experts such as human scientists, designers or even planning experts.

Too often have we seen the results of a station development treated as a simple case of real estate development, with architects designing the built environment following solely a client’s brief and their own authority, disregarding the impact of social control and cohesion.

Prior desk research had revealed that in neighbourhoods with “good” social cohesion, interaction and diversity levels, the perceived level of security was usually quite elevated.
To be sure, perceived security does not always match objective security. Perceived security resides in our head. It results from our emotional capacity to trust, manage and possibly intervene in a situation. Consequently, perception is emotional and for that reason requires a non-technical and human scientific approach.

The idea was backed by UITP and a palette of operators and authorities in urban public transport in Europe:
STIB, Brussels; RATP, Paris; StorstockholmLokal Trafik, Stockholm; Sporveier, Oslo;, Jonköping Lanstrafiken; VVM De Lijn Flanders; Metro do Porto, Porto; Istanbul Ulaçim; as well as the Flemish Government, the Cabinet for Equal Opportunities of the Brussels Capital region, IBM, Schréder and Clear Channel.

The team

We engaged our multidisciplinary team of experts in anthropology, sociology, psychology, design, architecture, urban planning and engineering developed a research that would change the perception of public space and public transport space.

Going beyond the traditional CPTED theory (Crime Prevention Through Environmental Design, °1970-ies), our methodology focuses on the necessary intertwining of design and human engineering of public space as a comprehensive and soft approach to improve perceived security, creating a higher quality public space.

SPIN-UP (Security Perception in Inter-modal Stations for Urban Public transport) was about to see the world.

Metro de Porto - Portugal

Sustainability and density of cities

Given every day more people go and live in cities, the demographic density of cities is growing - which no doubt, for sustainability reasons is preferable over the creation of an urban sprawl but which in terms of urban planning and if no regulatory framework is available poses a serious challenge to the availability of public space for meeting, greeting, leasure and entertainment.

Therefore we believe urban planning, urban 'greening' and mobility need to go hand in hand. In this respect we also refer to the problem created by urban heat islands as described in the chapter 1.2 of this desk research.

Why support and promote public transportation?

First of all, public transportation can be a good tool to promote efficient land-use (cfr chapter 1.3) as well as physical and social mobility and is essential in the creation and maintenance of attractive cities. Therefore besides moving people from A to B, public transport is also the blood in the veins of cities. It plays an essential role to:

1. Promote and develop a sustainable environment for current and future generations
2. Maintain and improve the quality of life in cities
3. Promote and develop physical and social mobility of citizens
4. Nourish social equity and inclusion by providing access to transport to the majority of citizens
5. Foster the economic performance of cities and communities

Fostering the attractiveness and the sustainable development of cities implies for PT-operators and their authorities the need to develop a long-term vision to plan and invest in line with demographic growth and foster economic development, They can achieve this improving their performance taking into account a range of 'physical' and 'emotional' aspects:

- plan the development of the network and stations considering a minimum walkway from and within residential and occupational zones to allow for efficient door-to-door mobility
- plan a widespread, accessible, safe and intermodal network with interesting hubs, if required make sure transfer stations are both interesting and allow swift transit
- allow for affordable tickets
- a strong and open identity rooted in the cultural diversity of the city and in return,
- the sense of co-ownership by customers leading to a better dialogue, social control and improved maintenance

“Success is a win-win.”

To be sure, success is a win-win. It requires mutual trust, sense for detailing, know-how and continued effort.

As referred to, we have seen in our research many examples of well-conceived stations from an infrastructural and engineering point of view. However, the infrastructure is often tarnished and even destroyed because the user doesn’t care or doesn’t feel recognised. His indifference relates to his relationship as a user to ‘the authority’ as a vast concept, because of the ‘them against us’ feeling, because of the ‘they do not know us’.

It is therefore quintessential to know and recognize the user in his needs and aspirations. Networks that adopt a respectful and understanding attitude towards their customers are more attractive than the networks who provide a stern infrastructure design and speak a language of authority than the networks that provide a closer-to-home setting and speak friendly.

We believe it is important to invest in quality space through prevention, communication and awareness in order to stimulate a positive attitude of passengers to the network.

SL Stockholm - Sweden

The latter doesn’t exclude that when, for security reasons, the so-called preventive attitude is not applicable, a more repressive tone of voice or attitude should be adopted.

Our research has consequently confirmed that in order to improve the perceived level of security of PT (Public Transport) networks in a sustainable way, three main goals in terms of design should be pursued:

1. To generate a business environment attractive to clients, the latter must associate their journey with an agreeable environment; if not, they may change their purchasing patterns to alternative transport modes. An agreeable environment implies:

a. Effectiveness and punctuality of the transportation,
b. Safety, security and serenity of the experience,
c. Perception by clients as an experience that responds to a positive image and recognizable life style

2. To offer an operational performance that allows the PT Operator to keep the production facilities and production tools visible to clients in a clean and pristine condition using efficient maintenance resources. This means keeping the network permanently clean, controlled and fully functional in a sustainable way.

3. To interact with customers engaging them in the surveillance of the network and in the creation of a welcoming environment - to involve passengers / clients as a positive and active part of the security equation. As referred to earlier, success is a win-win and can only be achieved by developing a sense of ownership with clients and staff and providing a network that is cherished by both.

Hence in our research findings we draw a line between the context and the actor.

The context:

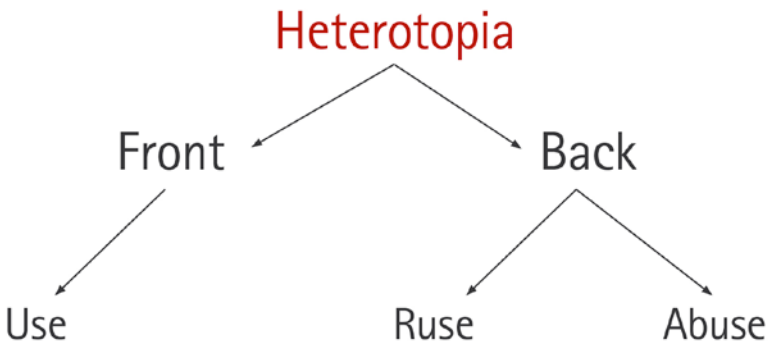
A “Heterotopia”

The heterotopia (Michel Foucault, ‘Of Other Spaces’/‘Des Espaces Autres’, 1967) concept allows for the fact that the nature and quality of each public space/urban public transport station is strongly influenced, if not defined by, the nature and quality of the surrounding neighbourhoods. In order to improve perceived security, it is important that stations serve beyond their functional status as a nodal point and adopt the status of a human interactivity platform.

STIB – Brussels, Belgium

Secondly, it is important to point out that even if modern public transportation networks use proprietary/semi public premises, they should be considered “Heterotopias” given users of all ranks, status, gender, social, ethnic, cultural, religious and intellectual backgrounds are welcome under the sole condition that they respect ‘the rules of the game.’ These ‘rules of the game’ imply, for example, that they pay for the journey and behave according to an explicit and implicit body of rules. No one group should dominate the space nor impose its own behaviour or rules upon other clients/staff present at any given time.

The organisation of space in the Heterotopia:



Front Space - Back Space

Likewise, this implies that infringements of these unwritten codes of conduct will not be tolerated. Therefore, prevention and dissuasive information prior to imposing repressive measures is crucial. The heterotopia status of the station also implies that users are to be considered as citizens and clients first, and consumers second, since not all clients are consumers.

The “Heterotopia” status diminishes the risk of tension and other accumulations of negative emotions. It also brings extra vitality to public transportation in a sustainable way.

As we equate a PT-station to a heterotopic public space, we come to the notion of front and back space behaviour.

Front space behaviour is defined as the behaviour that is expected in a public space and meets an explicit and implicit body of rules. This would include, for example, the way passengers use a seat, sitti¬ng on it as the designer intended.

RATP – Paris, France

Elaborating on this example, back space behaviour would mean the user uses the seat in a unexpected or even unwanted way. Back space behaviour can be defined as behaviour one would normally only reveal at home or in another private space, not in public.

The heterotopia follows a code – formal or informal - of the accepted ways of using the network is in use.
But society evolves, as do codes-of-conduct and conventions.

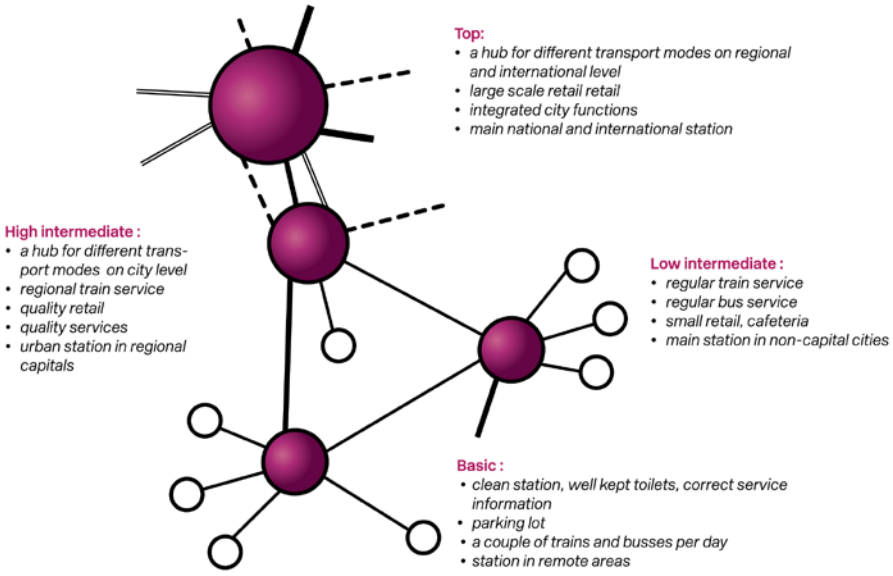
What was impolite 'ruse' in the past might have become an acceptable or relevant
way to behave today and a brand new behaviour might update another from the ruling code-of-conduct.
No matter the network, acceptable behaviour must be first circumscribed and made public before
the PT operator can accept it and possibly allocate resources to enforce it.

We recommend the design & human engineering approach to consider and:
a) foster the "correct" use of the PT network and services, be transparent on what is "correct"
b) avoid that unconventional forms of use of the PT premises by some passengers (ruse) becomes annoying and negative nuisances to others,
c) dissuade abuse, make it easy to detect and to repair,
d) enforce the code-of-conduct ensuring a balanced mix of "educational" and a "repressive attitude" to avoid extra sources of stress.

The hierarchy of the city and the hierarchy of a station

Antwerp is not Mumbai, Caracas is not Moscow, Paris is not Shanghai, New York is not London. Likewise we can refer to stations. As with cities, the attractiveness, quality and kind of a station is defined by its complexity, by the number and different modal connections, the distance of its connections, the complexity of its organisation and facilities and the quality of its services.

An interchange with High Speed and airport connection will attract a different audience than an
interchange with only urban and regional connections.
High Speed and airline passengers are likely to have a different time frame in front of them than
an underground traveller whose next train is in 90seconds. Facilities and services need to be adapted to these practical travellers' expectations.
Along the same lines, we have observed that the level of development of a station also depends the retail potential of the station, hence the possibility to generate non-rail income



The actor:

Mobility and Community services provider

Independent of the heterotopia or hierarchical status of the semi-public space as described, PT-operators should position themselves as mobility and community services providers, i.e as key actors in development of attractive cities. Indeed, PT networks are excellent tools that link neighbourhoods, help communicate and promote social cohesion. We expect them to drive us from here to there, inform us of incoming trains and buses and possibly also entertain us while we do some shopping in their premises surrounded by attractive music, art, lights, etc.

This position as mobility and community service provider can only be achieved as long as the PT actors excell as to deserve this status of respect and authority. In practice, this implies that the PT network is visible in the city, with clearly signposted entrances/exits and signage to and from the platforms, reliable timetables and performance information, premises, facilities and services that are kept clean and maintained in perfect working condition, staff that adopt a customer friendly attitude, a good combination of commercial and other services on hand... in short, that intuitively, we feel confident about the network and its operator.

STIB – Brussels, Belgium

Along with the client confidence comes their identification with the network. Encouraging clients to identify with the network can be promoted through a series of sensorial measures such as the integration of public art by local artists, references to activities in the surrounding neighbourhood (museums, music halls, universities, squares, etc.) clear signage, information and other forms of communication.

The practice

The above mentioned 3-fold theoretical concept to design public space and public transport space can be implemented in 3 levels of intervention:
- infrastructure
- equipment
- day-to-day operations

In conclusion

The research findings confirm that perceived security in urban public transport cannot be satisfactorily addressed from a technical perspective only. It requires insight and understanding of the context, culture, social and economic dynamics of the environment and station surroundings along with an understanding of the mechanisms and emotional reactions of people.

SPIN-UP honours the principles of human interaction in the heterotopia and stresses the operator's position as mobility and community services provider. It is currently applied by PT transport operators and specific consumer oriented businesses in Europe. SPIN-UP is praised for its impact leading to positive social and customer relations as well as maintaining, if not reducing, the cost of maintenance and equipment.

Under this research program we intend to further examine how better connectivity, introduction of new energy, ICT and general management solutions have an even improved impact on perceived security.

Design tools for safety and security

The most reliable and thorough way to ensure basic safety and security in the interchange is to embed them in design. It is much more effective to avoid creating spaces that offer opportunities for crime than to redecorate them later with surveillance cameras and security gates.
Inside the interchange
Openness and good visibility – well-proportioned, bright and airy spaces contribute to positive experience and feeling of safety. Enabling people to see others and be seen by others decreases opportunities for criminals.
Spacious platforms – sufficient space for waiting and movement prevents crowding of passengers and ensures safe distances from moving vehicles.
Multiple accesses – the ability to choose one's own way to move through a space and by that regulate social interaction, contributes to feelings of satisfaction and comfort. Access from different directions also distributes the flow of people during peak times.
Clarity of space – all isolated locations, such as dark corners and view-

blocking obstacles should be eliminated to avoid creating places for hiding and harassment.
Sufficient lighting – well-lit spaces ensure better visibility, thus are safer in use and more secure. Daylight is preferable where possible.
Marking - it must be clear to interchange users where they can stand and walk safely, where they should be cautious and where they are not allowed. There should be signs perceptible to people with disabilities.
Suitable materials – selection of materials to use must be done thoughtfully according to local specifics and needs of the interchange. All surfaces should be easy to clean, durable, anti-slip and vandal-proof.
Climate protection – shelters from wind, rain and sun should be provided at waiting areas to ensure physical comfort of travellers. Any construction designed for climate protection should not obstruct views. (PIRATE, 2000; Transport for London, 2009)

Fig 9a Platform at Stratford DLR station (UK). (Source: Transport for London, 2009, p.24)

Interchange access zone

Good visibility – the most important principle for safety of all participants in traffic. Removing all view-blocking obstacles near crossings of vehicular, bicycle and pedestrian flows decreases risk of inattention and subsequent accidents.
Slow speed zones - where motorized vehicles meet pedestrians and cyclists, speed limit should be lowered to prevent possibilities of accidents.
Traffic lights – regulated intersections are safer than zebra crossings, and countdown traffic lights have proved to be easier understandable by pedestrians. (NYC Department of Transportation, 2010)

Sufficient lighting – most accidents occur at night when visibility is limited. Street lighting that does not cast long shadows is preferable as it creates less contrast in view and decreases opportunities for criminals.
Marking - it must be clear to all pedestrians, cyclists and drivers where they are and aren't allowed and where they should be more attentive. There should be signs perceptible to people with disabilities.

Management tools for safety and security

In addition to design solutions, there are many ways to improve safety and security of an interchange by successfully managing its operation.
Maintenance – regular and accurate check-ups and repairs of interchange premises and facilities. According to the Broken Windows theory of social scientists Wilson and Kelling (1982), physical deterioration of a place often leads to further vandalism and crime. On the contrary, well-kept spaces give the users a feeling they are being cared-for and motivate them to use the interchange with care.
Cleaning – unpleasant odours and sights of rubbish make people feel insecure as it shows that well-being of travellers is not a priority. When spaces are kept clean and tidy, vandalism is also discouraged. (BILAN, 2006)
Presence of staff – regular interchange employees in uniforms who can also provide useful information increase perceived and actual security in a more 'friendly' way than armed security guards. Presence of staff makes the passengers feel cared-for and secured. (PIRATE, 2000)
Climate control – sufficient heating and ventilation contributes to physical comfort and health of travellers and ensures a pleasant waiting time. (Transport for London, 2009)
Sufficient information – having easy access to up-to-date travel information also reduces passengers' feelings of insecurity and anxiety.
Video surveillance – cameras within the interchange help inform the staff about emergency situations. The presence of too many cameras, however, does not increase perceived security. On the contrary, it makes passengers wonder if they are endangered and should be alert for possible threats.
Emergency management – in case of accidents the interchange staff should have a clear plan of action. Emergency equipment should be easily available for travellers within the interchange. (PIRATE, 2000)

Policy tools
EU policy – a common approach for the protection and resilience of mass transport infrastructures and protection of travellers. For developing such a policy discussion and consultations between users, operators and suppliers should be carried out and a common methodology risk assessment should be developed. (EOS, 2009)

2.2 Building envelope

In this chapter we will take a closer look at how the building envelope of the station can contribute to sustainability, mobility and increasing the quality of stations' public spaces.

The main role of the building envelope is to create space where public domain, physical comfort and transportation services are combined under one roof. To increase physical comfort, and at the same time try to achieve sustainability goals, the building envelope of the interchange should employ both passive and active building solutions. Under passive solutions we understand using building techniques that take advantage of local climate, materials and functional solutions, without using large energy and resources consuming technologies. On the other hand, active building solutions (such as artificial lighting or air-conditioning) are a necessity especially at large and complex interchanges structures. In an ideal station model, both passive and active solutions should be present and balanced, according to the scale and hierarchical position of the station in the network.

Efficient cooling and heating

New interchange stations combine both passive and active inner-climate systems to achieve optimal air temperature and humidity levels. The first step to low-carbon, low-cost and low energy internal environment solutions is to establish different "environmental zones", (Hauptbahnhof Berlin, Germany) where the degree of cooling or heating is being tempered "according to occupancy, dwelling times, relative comfort and independent factors such as revenue" ("Rail Interchange", Buro Happold).

The large scale of the station building and its external facilities often requires that passive or natural systems (requiring minimal or no energy) must be supported by motorized or other systems. (the so-called mixed mode, natural / mechanical systems) For example, in order to regulate temperature and achieve comfort conditions to 95% of the year, natural ventilation was developed using automatic motorised windows in the Grand Hall of the El Haramain High Speed Railway Station (Saudi Arabia) along with a radiant floor ("cooling floor") which provides relief in extreme temperature periods ("Rail Interchange", Buro Happold).

There are also good examples of combining building elements with solutions to eliminate pollution coming from (still) highly pollutant bus transportation. One of those examples is Anaheim Regional Transportation Intermodal Center with fixed openings on the facade, along with 14' de-stratification fans, that provide natural ventilation along with regulating carbon monoxide from bus exhaust.

Efficient cooling and heating can be successfully achieved on the smaller-scale stations by using local materials, which have proven their excellent microclimate regulatory properties throughout centuries of use. One of these examples is a series of small-scaled railway stations in the Japanese provincial towns, which use wood and wood-building local techniques to achieve not only visual, but also environmental qualities. (source: ("Benchmark of Asian Public transport Interchanges", UIC-Yellow design Foundation 2011)

Natural and artificial light

If we look closer at the type of activities that occur inside the multimodal stations, we see that majority of passengers use the space for walking (between different modi, platforms, outlets or parts of the station) or standing and sitting while waiting. Walking, standing and sitting involve high degree of interaction with the environment – inside the station environment it becomes more concentrated and dependent on different factors, among which lighting is one of the most important.

Different passengers needs have to be supported by appropriate pedestrian light engineering, which is essentially different from the light engineering needed to facilitate good functioning of the mobility system, motorized or rail-bounded. For example, an increased illumination from a users perspective is needed when:

- pedestrians perceive greater threats to personal security
- pedestrians are moving fast
- physical obstacles (stairs, fences) are likely on their trajectory

(source: "Public lighting for safe and attractive pedestrian areas", T Lester, Opus Central Laboratories, Lower Hutt, New Zealand, NZ)

Lighting can be used to create, communicate or contribute to the area's atmosphere, and should follow the specifics of the day or night situation. As stated in (Public lighting for safe and attractive pedestrian areas", T Lester, Opus Central Laboratories, Lower Hutt, New Zealand, NZ) " During daytime, natural light facilitates a safe, comfortable, efficient and enjoyable walking experience. During darkness, artificial lighting techniques should light the environment for the particular needs and preferences of pedestrians to maintain that standard of walking experience.

In the same source we can find following main key elements of good light engineering that have impact on pedestrians primarily, and both applicable for natural and artificial light:

- lighting uniformity is important. It can be managed through luminary output, light size, mounting height and spacing
- lighting colour can optimize colour rendering – it can recreate natural daylight conditions, or to combine and enhance the colours of the pedestrian environment
- the significance of shadows within pedestrian environment needs to be considered
- the luminance needs to be reviewed from the perspective of the pedestrian activity types and locations, and potentially matched to desired pedestrian activity types and locations

- lighting and the specific installation (e.g.height, spectrum of light

equipment) can influence perceived security. This effect needs to be considered and managed to ensure the pedestrian lighting scheme communicates the appropriate message to pedestrians about the use of pedestrian area.

The benefits of natural light to the human well-being are generally known, from physiological and psychological effects, to social and behavioural. However, the complexity of stations as they rise on the hierarchical scale often has to compromise with the provision of natural light in their indoor spaces. Providing as much as possible natural light in the stations is a complex task. New interchange stations aiming to be sustainable, combine natural lighting concepts of dynamic facades. Dynamic facades use special elements (such as ETFE pillows,e.g.) that respond to the environmental conditions by adapting the amount of daylight and solar gain that enters the building.

Using specific sets of colours, with positive reflecting and contrasting effects, can reduce over-illumination of surfaces. Finally, different illumination zones can be automatically regulated in order to maximize energy savings.

Natural and artificial light together with thermal conditioning is an integral part of the human comfort at the station. The presence of natural light promotes passengers' time-and-place orientation. The recent trends show the tendency to view the natural and artificial light components as one whole, rather than two separate systems.

Underground spaces

Maintaining the same (high) levels of lighting standards is quite difficult in cases where some of the present transportation modi are qualitatively disadvantaged. Underground spaces are especially vulnerable to this disparity in quality as a result of infrastructure conditions and location of the station. Usually the absence of natural light in long underground corridors in combination with low ceilings is the reason why they are not perceived as pleasant and sometimes unsafe. The recent technological developments, however, offer some solutions to treat the problem of absence of the natural light, by using optical fibre cables to bring natural light from the surface to the deeper underground layers.

The extensive underground spaces of major interchanges are heavily dependent on artificial light. Artificial light consumes a significant part of the electric energy consumption of the station. These costs can be

reduced by e.g. preventing over-illumination of the surfaces, modulating the light production in synchronisation with the arrival of trains, using environmentally friendly low-energy lighting elements (“Benchmark of Asian Public transport Interchanges”, YDF). This strategy includes identifying different illumination zones within the station area, each with different standards.

Bringing natural light in the underground spaces is also one of the currently relevant research and practice topics, and methods to reduce energy consumption. Using specialised software, (“Underground Passenger Comfort - Rethinking the current thermal and lighting standards”) the use of natural light can be maximized:

“Radiance software uses ray-tracing to accurately predict the lighting levels that can be achieved in the space. The illumination of underground surfaces relies on reflected daylight values. Analyses at platform level (20 meters below grade) revealed that placing the platform at the north of the site would allow the southern mid-day sun angles the greatest access in clear sky conditions. For natural daylight to reach the platform level, a northern ‘light wall’ with a high surface reflectance value was tested. With Radiance Daylight simulations, skylight additions to the typical station were tested. Over 2000 lux was shown to have been available during the key station times in winter nearest the skylights, positively indicating that the goal of exceeding 100 lux should be achievable even in the areas furthest from the skylights (“Underground Passenger Comfort - Rethinking the current thermal and lighting standards”).

Green layers

Large-scale interchange stations consist mostly of large buildings, with many of them flat-roofed. Flat roof surfaces of these structures offer great potentials to contribute substantially to lowering the carbon emissions and better energy efficiency.

“Reducing the fuel costs of the buildings that have green roofs leads to a reduction in the production of carbon dioxide. This reduction could be further increased if solar panels were installed on the roof. Green roofs are known to increase the efficiency of solar panels by acting as a cooling agent. Furthermore, plants on a green roof also reduce the amount of carbon dioxide in the atmosphere through their biological activity.” (source: “Green Roofs, Benefits and Cost Implications”.)

Green roofs work as insulation membranes, but also as regulators in reducing the (storm)-rainwater run-off. Many commercial buildings in densely built-up city cores use green roof surfaces as additional green

space, sometimes even open to the public. In the context of the large interchange stations, presence of green roofs can diminish the negative impact of the large-scale stacking-up of the infrastructure, especially if the station is located in a central area, which lacks natural features. (e.g. new Transbay Transit Centre in San Francisco) The presence of green roofs brings improvements to the appearance and appeal of the station. Even at small-scale it softens the artificiality and perception of stations as pure functional nodes.

Facades can also be covered with green layers, especially degraded and aesthetically disadvantages facades of older stations. In their “green wall” project on Edgware Road underground station, Transport for London (“Delivering Vertical Greening”, Transport for London) transformed the external wall of the stations to a vertical garden, with primary objective to reduce the air pollution. But green facades thanks to their isolating property have an energy reducing impact.

The important potential of including green layers on the existing stations is increasing their aesthetic values, and therefore making them more attractive to users. The possibilities to introduce other functions in the station surroundings, or expand the non-motorized modi of travel in the surroundings can be increased with this approach.

In the post-evaluation of the Edgware Road project, TfL conducted a survey amongst citizens living and working nearby the station. Cultural benefits are of prime importance with aesthetics being one of the main benefits mentioned by people living and working in the vicinity of green walls. The results are summarised in the following table: fig 10

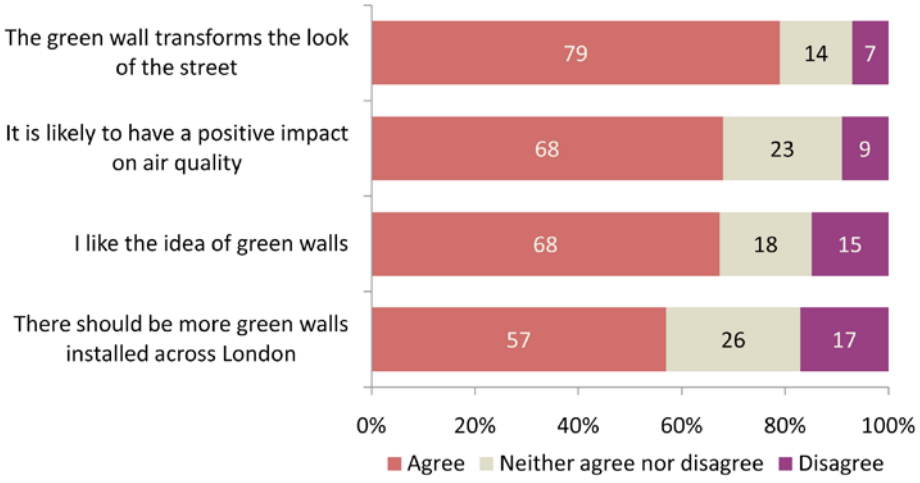


Fig 10: “Delivering Vertical Greening”, Transport for London, 2012

Urban Heat Island prevention

The installation of green layers on stations building surfaces (including rooftops) is an excellent solution not only to energy efficiency, but also as a preventive measure to the urban heat island effect. Green roofs bring back (though only partially) the same evaporative cooling effect that is lost by cutting trees and taking away grass surfaces in the city. A green roof not only prevents the building's roof from absorbing heat, but also cools the air around it, diminishing the urban heat island effect. However, installation of green layers may be expensive, demanding meticulous maintenance.

Another effective and relatively cheap way of preventing formation of urban heat islands is the use of light coloured materials for façades or rooftops. Building elements that have dark coulour absorb more light, and emit more heat. Same as wearing a black shirt on a hot summer day – black shirt absorbs intensive sunlight and emits heat on the skin of the wearer, making him feeling hotter. Wearing a white shirt , on the other hand helps reflecting the sunlight, and keep the wearer cooler.
The rate at which an object can reflect sunlight is called albedo factor. Dark building surfaces have low albedo factor – they reflect very little or none sunlight, generating heat emissions. Because of this effect, a good solution to increase the albedo factor is to use as much as possible light coloured building materials, or simple, light coloured surfaces. (source: S R Gaffin, M Imhoff, C Rosenzweig, R Khanbilvardi, A Pasqualini, A Y Y Kong, D Grillo, A Freed, D Hillel, E Hartung. Bright is the new black—multi-year performance of high-albedo roofs in an urban climate. Environmental Research Letters, 2012; 7 (1): 014029 DOI: 10.1088/1748-9326/7/1/014029)
These basic techniques can also help reduce low carbon emissions, as a side-effect of lowering the heat island effect.A research and simulation by the prof H. Akbari, (the former head of the Berkeley Lab Heat Island Group and now Hydro-Quebec Industrial Research Professor at Concordia University in Montreal), has shown that every one-percentage point increase in a square metre of urban reflectivity (materials with higher

albedo) could offset seven kilograms of carbon dioxide. Prof. Akbari went even further and stated that “if every city in hot and temperate climates changed its roofs and road surfaces to reflective colours, the effect would be the equivalent of taking every car off the road for the next 50 years.” (source:insciences.org/article.php?article_id=9299)

However, building a glaring, all-white station can not always be the solution, leading to little variation in architectural expression, and therefore, less attractiveness and people may not be happy using it every day. Applying low-reflectivity coatings with other colours than white can be a solution, knowing that these kinds of coatings reflect invisible radiation without reflecting all light. A kind of facial UV-lotion, (but then for buildings), allowing an object to stay relatively cool without sacrificing its dark colour. Similar coatings are already in use for asphalt surfaces by large highway road infrastructure.

Management tools

3.1 Low carbon policies and public transport

Clean fuel for motorized public transport

King's Cross Station , London

King's Cross Railway Station's new 280 kWp solar glazing system is expected to generate 175,000 kWh of electricity a year – saving over 100 tonnes of CO2 emissions. The £1.3m award-winning building-integrated project forms an integral part of Network Rail's green building programme. The array is made up of 1,392 custom made glass laminate panels which form part of the station's two large barrel vaulted roofs spanning the main platforms.

Improvements of the energy efficiency and use of less-polluting and sustainable fuels within the public transport network contribute significantly to the reduction of the CO2 emission.

In its "Green light to clean power, The Mayor's Energy Strategy", the Mayor of London requires from city's major public transport authority (Transport for London) "to lead in adopting energy-efficiency, such as:

- more use of clean fuel vehicles and clean technologies in its bus and taxi fleets
- adequate driver training as a way to reduce fuel use / costs
- use of clean vehicles and clean technologies for maintenance and service purposes"

Continuous measure and improvement of driving skills as well as secondary measures to promote "culture of clean driving" (such as more efficient use of gears, or use of fully automated vehicles) are not reserved only for public transport drivers. Promotional campaigns of this sort are often made for personal car users, as a part of CO2 reduction efforts on a broad level.

Incentives / charging policies at the city level

Energy efficiency can be additionally stimulated by introducing different incentives or charging instruments, of which the known examples are: (according to "Green light to clean power, The Mayor's Energy Strategy",TfL)

- congestion charging, which will reduce traffic volumes and encourage the use of public transport

- giving grants for adaptation to cleaner fuels, or for retrofitting of the motorized public transport fleets, through different energy saving trusts (on local, regional or national level)
- use of government-backed award schemes (such as “Motorvate” in the UK), which enables public transport operators to better monitor their fuel use, and save on the fuel and energy costs.

Low carbon policies at station level

Procurement and suppliers

Life-cycle approach in the selection of materials and its producers is an established standard in many green building practices (including stations), as well as the use of BREEAM and LEED standards to assess buildings and urban neighbourhoods.
Material selection and design greatly impacts the maintainability and durability of the station and its facilities. But using the BREEAM and LEED material standards can also distort the picture of what are real gains in terms of sustainability and low carbon emissions. There is also a significant difference between the way BREEAM and LEED assess certain uses and practices. As BSRIA (UK’s based Building Services Research and Information Association) states in their article “BREEAM or LEED - strengths and weaknesses of the two main environmental assessment methods, February 2009, bsria.co.uk : “BREEAM has long been able to adapt to local contexts. With BREEAM Bespoke, for example, the assessor can work with BRE to develop assessment criteria specially tailored to a building where it doesn’t fit neatly into one of the existing schemes. LEED, however, has not been created with this level of adaptability and it is not run that way. Instead it is fixed to the ASHRAE standards and the US way of thinking (for example, credits are awarded for having enough car parking spaces, rather than minimising them as in BREEAM). There are also differences in the way LEED calculates credits. They are generally linked to the US Dollar (especially the energy credits), which means that if the exchange rate is unfavorable, then the building’s rating could suffer.”

Using standard assessments has a tendency to focus on factors that are easy to measure, and sometimes they are not necessarily the most important.

With this in mind, Translink's "Transit Passenger Facility Design Guidelines" sumps up the following recommendations on the selection of materials:

- Use materials with an agreed minimum life-span for their application,
- Avoid materials with complicated repair, removal and disposal requirements, minimizing health and safety, air quality, and waste management impacts,
- Research recommended materials and processes to ensure proven performance in similar applications,
- Avoid materials with any potential negative environmental impacts, especially those materials likely to be regulated within a facility's service life, to minimize cost of future replacement,
- Design for durability and weather resistant materials, including interfaces between dissimilar materials that may result in reduced performance.

3.2 Station management: operation and maintenance

We consider the following categories as essential for the low carbon aspects of stations' operations and maintenance:

- energy (energy efficiency)
- water management
- waste management

Energy efficiency at station level

Station buildings and station operations today rely heavily on tapping energy from the city's or national electrical grids. In the last decades, however, we see that more and more stations include on-site renewable sources of energy, such as solar PV panels on the large roof and other horizontal surfaces. Those sources currently provide at its best up to 10 to 15% of the energy needs of the station.

Still, including solar power in the energy pool of the station is one of the most applicable practices. Other methods, such as use of wind power or geothermal sources have serious limitations, due to densely build-up station locations.

As described in UK's Railway Networks approach to renovate Kind's Cross station (King's Cross, Moving ahead), "We discounted wind turbines as the 1850s masonry would not be able to withstand the additional load, and the surrounding buildings would cause the wind to gust and reduce the turbine efficiency. Geothermal piles were also unsuitable because the subsurface space under King's Cross is already heavily congested with underground railway lines and access tunnels."

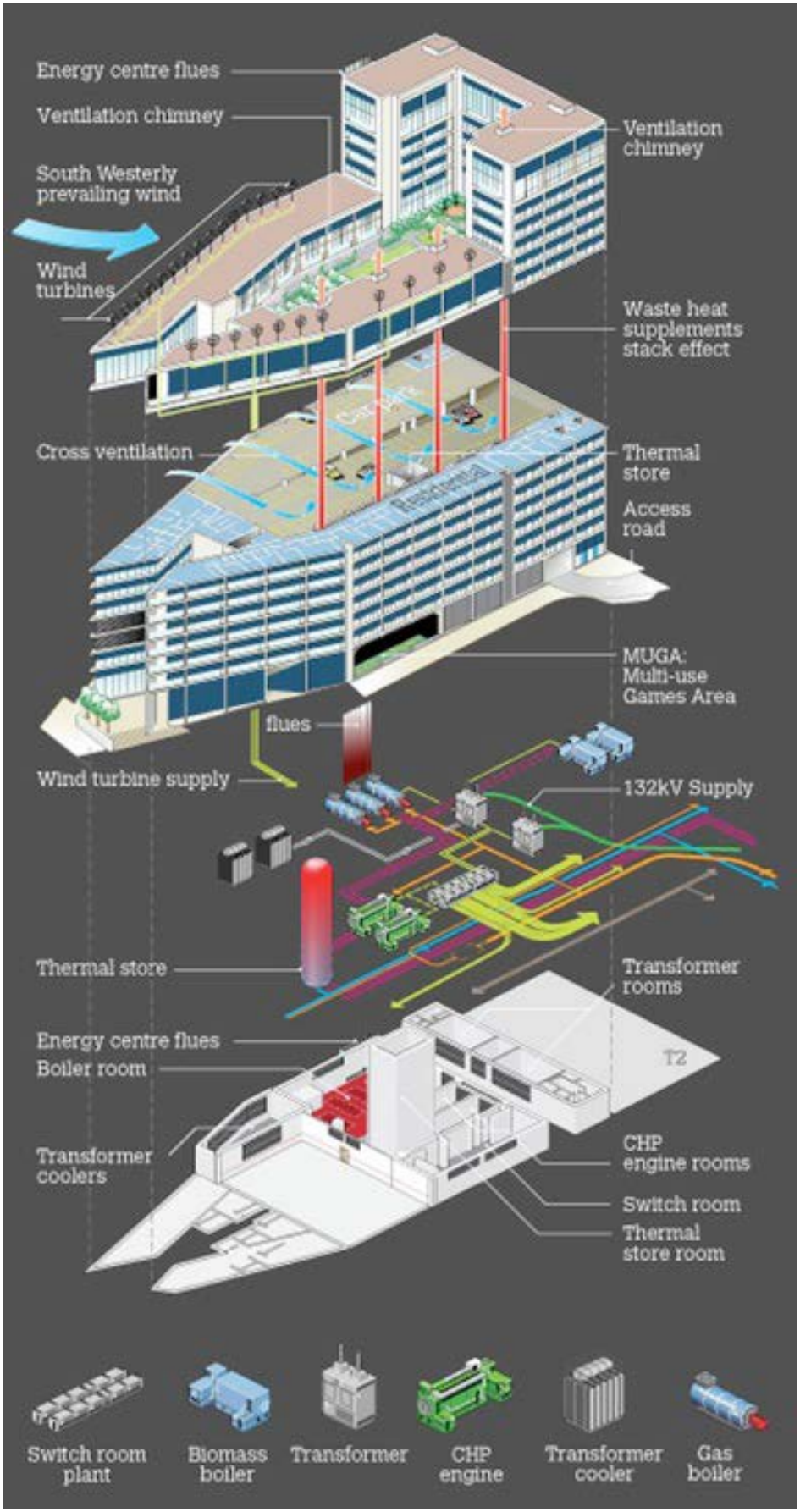


Fig 11: "Kings Cross Station", "King's Cross, Moving ahead", Railway Networks, UK, 2012

Today it is impossible for a station to be fully energy-independent from the national grid. The good news is that with the development of smart grids, stations could no longer be just passive consumers of energy, but also its “producers”.

The idea behind smart grids is to use technology and smart management to facilitate energy flows both to and from the grid. In the future, this could mean that station can give back to the grid the energy coming from its operations. On the smart management level, businesses, station services and other commercial outlets in the station and in its surroundings will be able to see how much electricity they are using at any given time and moderate that use. This management system then allows development of different financial incentives policies, such as earning energy credits, or points, and getting discounts and tax reductions.

The use of renewable sources for different energy demands (electricity, hot water, heating, cooling) in combination with smart grid is the next step in increasing the sustainability of the whole urban system, including stations and other transport facilities. Taking into account that some of the present renewable energy installations (such as wind power turbines) cannot be efficiently used in dense urban areas, the following examples have more potentials in the future: the re-use of excess steam or hot water from district heating systems, the use of biomass and waste as substitute for traditional fuels (coal, oil, gas) in heating and power plants, and use of geothermal sources.

Stations as energy source

Old trains (constructed before 1960) consume electricity to provide traction to their bogies (wheel sets under the vehicle “bed” floor) and brake using two different methods;

1) using mechanical brakes (for hard braking) and
2) using electrical braking (softer braking).

Electrical braking generates electrical power on the vehicle and old trains were usually equipped onboard with huge electrical resistances to dissipate (consume) the energy generated while braking. This is why lots of old trains are very hot under normal operation.

New trains (conceived from 1960-onwards) are more sophisticated and capable of using the energy generated while using electrical braking. These trains give the energy back to the catenary (the power wire suspended above the track, or to the “third rail” on the ground) while braking on electrical braking.

The energy given back to the catenary is either consumed somewhere in the rail network by other trains demanding traction or dissipated by the network resistances.

In short, the rail network manager can nowadays manage the amount of power it buys from the electricity providers and keep the trains running with a smaller amount of Kwh-per-train than some decades ago. The capacity of giving back the energy while braking is very interesting as it decreases the power bills to the train operator because the net consumption is much lower than the gross consumption.

Nowadays, most networks are managed by an independent infrastructure manager (usually responsible to sell the catenary electricity to the users of its network) and used by train operators (the consumers of electricity from catenary), almost all rail fleets are equipped or converted to this consume+give back technology.

There are also examples of trying to capture the breaking energy, store it and use it for energy needs of the station self. As a pilot project in Bielefeld, Germany shows, (source: “Breaking energy recovery systems”, Ticket to Kyoto workshop publication, May 2011) this method needs to use (spatially) large batteries, and from the technical point of view, the best points to produce and store the breaking energy are railway terminal station, while interchange stations are less suitable.

Today most stations and other rail buildings are mainly consumers of electricity. They do not generate power, traditionally; unless they are equipped with photovoltaic solar panels, wind turbines (incompatible with the human settlements in the dense inner-city urban areas) or gas turbine engines (a sort of quite efficient electricity generators). Gas turbine engines (some called “dual mode generators” and other newly coined eco names) are common in factories where electricity and heat is needed for the manufacture operations. Nowadays they are also used at large, complex interchange stations as a part of CHP (Combined Heat and Power) configurations.

Another interesting pilot project of sustainable energy generation at the station is the energy generated by urban crowds, using the floor tiles that harvest energy from the footsteps of passers-by. Theoretically the idea has enormous application considering the number of people visiting stations, malls, and public spaces in general. The “harvesting” floor tiles are made of rubber and recycled materials. Each tile can generate up to 3 watts of electricity per hour, converting kinetic energy released through the footsteps of passersby into electricity. The tiles are designed to withstand any weather conditions. The tiles can be fitted to any existing

floor or structure, and can be installed temporarily. When excess power is generated through the tile it can be stored for future use, with the help of a lithium polymer battery. To prevent uneven power transmission, delivery filters and feedback sensors are used so that this system can be trusted 24×7. By directly involving passers-by in the process of energy generation, this solution can also be seen as a powerful awareness-raising and communication tool. (source: "Benchmark of Asian Public transport Interchanges", UIC-Yellow design Foundation 2011)

Another example of sustainable energy generation (that can be considered in the future as one of the station building's elements) is the use of bio-adaptive facades. As described in their BIQ house project for IBA Expo 2013 in Germany, (source: Arup Associates News September 2012) Arup engineers are proposing façade elements filled with microalgae, that can generate energy and provide shade at the same time. By including this and other new approaches, we can conclude that "energy independence" or " building as energy source" trend is to be considered by future station complexes as well.

Water management

Water management at the station level

"At first glance, the water and wastewater sector does not offer obvious opportunities to reduce a city's carbon footprint" (Sustainable Low Carbon City Development in China, The World Bank). However, if these two aspects are put into perspective of a combination of different sectors, its contribution to sustainability is essential. Considering that water is a scarce resource in many regions of the world, the recycling of wastewater and production of clean water is a matter of high priority. Energy efficiency in recycling is also one of the keys to sustainable development.

At the station, as well in the city as a whole, energy intensity of (clean) water and wastewater treatment can be reduced. Several approaches and strategies exist. To name but a few:

- employing low energy water systems that integrate re-use of rainwater and storm-water in general,
- re-evaluation of clean water intake strategies (in view of the energy use implications) for maintenance and for general purposes,
- better (and possibly automated) water demand management,
- optimization of water infrastructure,
- use integrated building and landscape design strategies to manage an re-use water on site (e.g. roofs and other inclined surfaces as water collectors).

Water management in the station surroundings

In the area surrounding the station, water issues become quickly part of the larger urban context, where so-called open water has traditionally significant landscaping role. With raising awareness about sustainability and a holistic approach to urban planning, both the landscaping and functional role of water as a resource and a vital element of the city's ecology, is gaining more and more importance.

Storm-water management techniques therefore have great influence on making the station surroundings more sustainable. In the Translink's "Transit Passenger Facility Design Guidelines" the following elements are mentioned as recommendable approach in designing water-friendly public space:

- use of pervious pavements that allow more natural permeability and filtration of contaminants,
- green surfaces with captured surface water (sometimes also called "rain gardens"),
- landscaped filtration and collection areas.

Waste management

Waste management at station level

With increasing number of passengers and higher frequency of trains and other public transport modes at the interchange stations, the volume of waste generated from commercial outlets, passengers and station operations are growing as well.

Treating waste as a source of material and energy, rather then as a permanent disposal is one of the main aspects of sustainability. How can better waste management contribute to lowering the energy use, and therefore contribute to low carbon policies at the stations? This aspect and its potential applications in stations will require further research, especially

if we want the stations to be integral elements of the larger sustainable urban system. As mentioned in a study at the University of Florida already in 1993, (in the "Biochemical Methane Potential of Municipal Solid Waste (MSW) Components", by J. M. Owens and D. P. Chynoweth from Agricultural Engineering Department, Rogers Hall, University of Florida, Gainesville, USA) "both municipal and consumer waste can be the prime resource for the production of methane", suggesting the great value of waste as a source of renewable energy. In the developing countries, where waste management on the urban level is problematic, the idea to focus on energy gaining from the waste as an incentive for better waste management is present in several researches. In his research on the topic of improving the waste management in Accra, Ghana, Edward Dotseh Anomanyo from Lund University ("Integration of municipal solid waste management in Accra: Bioreactor treatment technology as an integral part of the management process") defines new integral approaches to combine waste collection, waste process and energy gain, as a way to generate profit and partly, energy security for the city. Considering the amount of waste generated at different stations, due to high number of passengers and presence of commercial outlets, they can be seen as a vital contributors in the larger urban waste management and energy scheme.

Source: World Bank 2005.

In their "Sustainable commitment - annual report" the Dutch Railways (NS) describe their methods and future strategies in dealing with waste management as a way to optimise the overall efficiency of their stations. Starting in 2011, NS improved the recording methods of different waste flows, "in order to be able to grasp the scale and characteristics of different flows, such as:

- industrial waste (from workshops, depots and repair rooms, as well as write-off materials),
- office waste (including waste as a result of renewing the office equipment),
- consumer waste (from commercial outlets, their customers, and train / public transport passengers).

In the same report they state that “The analysis of waste flows resulted in defying new waste management strategies, but also in concrete public actions. One of the public initiatives has been to organise a design competition on how to re-use old, written-off departure / arrival charts” (NS, “Sustainable commitment - annual report”)
On the spatial level of the station, providing enough specialized waste bins to separate different waste is just one of the aspects. Reducing the “waste mileage” by centralising the collection of waste, and increase the cooperation between the station management and the waste collection companies is important. In its future plans, stations should take into consideration that more waste is going to be re-used within station yards or buildings themselves, and therefore think about adapting those facilities.

Another aspect of waste management at the station level is its importance for the passengers / customers experience. This issue has two sides: first, passengers and customers of the station (or users in general) expect to sit in clean coaches and vehicles, wait on clean platforms and enjoy clean public areas regardless of their chosen mode of transport. Secondly, they also expect to have their own “freedom in creating waste”, mostly meaning being able to snack or drink casually. This second side is a cultural phenomenon, which has great impact on how to communicate and organize user - generated waste collection: pleading for understanding and eco-conscience, or be plainly prohibitive?

3.3 Finance and co-operation frameworks

Efforts to make stations and station surroundings more adaptable to low carbon city concept are made increasingly complicated by the fact that large number of stakeholders are involved in their development (PT organisations, infrastructure operators, external services, real estate developers, municipality, residents and businesses). Their interest in more energy-efficiency may be mutual, but can also easily generate a conflict. The complexity of this stakeholder platform likewise increases the complexity of the decision making process. It is therefore essential to implement clear and short decision making procedures.

As cited in “Funding Low Carbon Cities: Mapping the Risks and Opportunities”, “all of the stakeholders have certain resources necessary to develop station areas. These resources can be divided into four main categories:
- finance,
- land ownership,
- knowledge,
- proceedings (decision-making powers).

In order to achieve energy-efficiency and broader low carbon aims, main actors or leaders of sustainable change have to adopt a holistic view and make optimum use of all the resource categories, taking into account different interests of all relevant stakeholders.

In this respect, we refer to MTR (Mass Transit Railway) of Hong Kong as an example of achieving the high level of co-operation and financing. Their approach focuses on integrated operations at the station as a functional, commercial and meet-and-greet urban mode. The success of the operations is based on the fact that MTR acts both as PT operator and as real-estate developer of the land surrounding the rail. Given land prices increase in the vicinity of rail and PT in general, and the fact that profit from the real estate value is then re-invested in rail and station development, makes this system a state-of-the art approach. The financial model of MTR and its possible positive characteristics for other networks should be further examined.

Another interesting approach for the benefit of investments in PT is the example of Transport for London (TfL). Taken that the success of London's inner-city businesses depends on their physical accessibility, and that the inner city locations are prime revenue resource (in terms of land value) Transport for London developed a levy scale (called Community Infrastructure Levy) on the basis of which London Boroughs (local authorities responsible for local services) charges organisations who are located in the vicinity of a PT station.

In this difficult and complex process of financing the PT and its station, approaches and strategies on how to come up with co-operation models for more energy efficiency and less carbon emissions can be found on different levels and between different stakeholders.

Some of these co-operation models are strongly depended on proceedings and hierarchy. As an example, Transport for London works together with other PT operators on establishing clean fuel standards. At the same time they are the responsible authority for issuing of sustainable operating permits.

Other co-operation models show intentions to form active coalitions based on mutual knowledge and practice exchange between transport companies, private (service) companies and other institutional structures. As an example, NS Rail (source: Sustainable commitment - annual report) organizes specialized workshops with private companies (contracted service providers, such as waste collecting companies) in order to better understand the sustainable practice developments of each company and to come up with mutual solutions.

Consolidation of opportunities

The diversity of stakeholders and their interests is making the issues of financing more low carbon practices complex and difficult. Although most of the stakeholders embrace the "people, planet, profit" motto, finding finance for the low carbon agenda represents the key obstacle.
As stated in "Funding Low Carbon Cities: Mapping the Risks and Opportunities":
"Local authorities must understand investors' needs and interests. Given that local authorities will require private investors to provide much of the capital required, it is important that they engage with these investors to understand:

- what sort of investment vehicles they would commit to,
- what sort of investment returns they would expect, and
- what sort of risks they would/can accept in return for these returns.

These "rules of engagement" are generally known, and can be applied to financing any other major city feature, not only new generations of public transport interchanges. For specific features, more important is finding the right strategy, or as the authors of Funding Low Carbon Cities: Mapping the Risks and Opportunities" see it, "Many of the (financial) concerns relate to the question of how to consolidate the numerous opportunities into a single (or a small number) of opportunities to invest at scale."

In the consolidation of opportunities, implementation has the key role.
"Local authorities need to start implementing low-carbon projects and initiatives. Many of the obstacles to low-carbon financing relate to uncertainty about the real costs and benefits of these types of investments. Implementation can provide evidence of the effectiveness of specific measures, and generate the financial and other information necessary to inform policy debates" ("Funding Low Carbon Cities: Mapping the Risks and Opportunities").

In the report "A paradigm shift towards sustainable low-carbon transport – Financing the Visiom ASAP" K Sakamoto , H Dalkmann , D Palmer (Institute for Transportation & Development Policy, together with TRL and SLoCaT partnership) we can find following recommendations: "There is therefore a clear need for all transport-relevant financial flows to be reoriented towards sustainable transport, to achieve the required paradigm shift. In moving forward, a holistic strategy is suggested, involving the following elements:

- ANALYSE the impacts of financing decisions taken by relevant stakeholders on sustainability;
- SHIFT existing resources towards a sustainable direction;
- ADD / increase funding for those areas where resources are lacking; and
- PAY for the full costs of transport including environmental depreciation"

3.4 Stimulating new mobility cultures

In the "Green paper – Towards a new culture for urban mobility", (2008) EU Commission emphasizes on the need to involve more and more EU citizens in creating new, more sustainable oriented "culture" of urban mobility. The core of the new cultural values are better balance between motorized and non-motorized transport, increase use of public transport and sustainable modes such as walking, cycling and car sharing. There is also a strong social dimension in the new culture for urban mobility, advocating for more social inclusiveness and "mobility-for-all" approach, attractiveness, safety and perceived security, as well as raising awareness that urban transport is one of the main contributors to pollution and high-carbon emission in cities.

If we look at the several different sources (such as proceedings of SMILE EU Mobility research and "Gender and Sustainable Urban Mobility", from Deike Peters, a Thematic study prepared for Sustainable Urban Mobility: Global Report on Human Settlements 2013) that try to understand, define and recommend on how to approach culture and mobility paradigm, we can comprehensively conclude that the positive change depends on how well do we understand the needs of specific passengers / commuter groups (children, woman, young adults, elderly, commuters of all ages and professions) in the local context.

From the urban policy and planning point of view, there are several examples that show that change in mobility culture happens only if there are several simultaneously executed " actions on the ground". Policy must go together with positive change in the physical space. The city of Guangzhou (China) is a good example of reintroduction of bikes and a successful bike sharing program at public transport stations, in a country where growing economy also causes a dramatic rise in individual car use. The city of Medellin is a exquisite example of how a real impact can be achieved by a synergy of activities: e.g. development of cable cars, of EnCicla bike sharing system is combined with PT bus stations, and is realised together with development of adjoining public spaces.

Role of ICT

The use of ICT solutions serves as a glue connecting low-carbon initiatives with stakeholders, passengers, and physical space of the station. The idea of “smart cities”, where functioning of the many city services and public spaces depend on the procurement of digital information, automatized management and control, also transfers to the station and station surroundings.

Although “smart city” as a concept in general receives criticism (Saskia Sassen rightly warns that an over-managed urban space can go from “sensored” to “censored” in her article “Talking back with your intelligent city” for McKinsey Institute), it can not be denied that in the case of urban mobility and public transport “smart” becomes the golden standard for providing good service and efficient management. In this respect we can argue that privacy protection and protection of individual right is essential.

In coming texts, ICT will be observed as relating to all the levels of the station, from network level to human engineering, physical structure and management and policy level.

The role of ICT

4.1 Connecting the users with the network

According to “Connected Sustainable Cities” from William J. Mitchell & Federico Casalegno, MIT Mobile Experience Lab, there are three levels in applying information technology to create enhanced public transportation systems.

1. The system must provide sufficiently comprehensive coverage of the city.
2. Easy-to-use guidance systems, making use of GPS and (eventually) Near Field Communication, must be employed to make riding the system’s vehicles simple, trip planning straightforward, and minute-by-minute personal scheduling possibilities.
3. Transit systems must embrace the software that riders use.

This last point is especially important, because it opens the doors to combine utility software showing formal travel information (timetables and routes) with more informal way of planning the trip, such as using social networks to move around the city.

As a conclusion, the MIT Mobile Experience Lab researchers offer the following recommendation: integrate mass transit systems with advanced information services to create systems people want to use.

With development of great variety of possibilities to dispatch travel and network information, (via personal devices such as mobile phones, or digital displays in the public space and on-board the vehicles themselves) public transport services are evolving from static systems (corridor based line-services) to more dynamic demand-driven services. The main contribution to the low-carbon city is reducing the amount of personal motorized transport and getting more people using PT.

Smart ticketing

Smart card ticketing allows seamless change from one transportational mode to another, without having to worry about different charging zones, or spending extra time on buying different sets of tickets. This service combines easy payment with easy access, and is based on the so-called Web 1.0, or transactional services type software. The more varied modi covered with one card- the better (e.g. the Dutch “OV card” that can be used in inter-city trains, local trains, metro’s, trams and busses in the whole country).

Just as any other payment card, public smart card can be connected to other non-related services, such as retail (e.g. Shanghai's "gong jiao" cards that besides public transport, also can be used in the retails stores).

4.2 Connecting users with the station

At the MIT Mobile Experience Laboratory, researchers and designers – working with the Régie Autonome des Transports Parisiens (RATP/Parisian Autonomous Transport Operator) in France – have developed the "concept of the Interactive Bus Stop that can serve as an electronic "concierge" and digital gateway into the offerings of the neighbourhood and the transportation system at large, giving passengers and residents the means to provide and access user-generated content".

Further, the physical bus stop itself can interact with the neighbourhood. Inspired by the metaphor of a garden whose plants grow and react depending on environmental conditions, the bus stop's LED facade can display ambient information, such as local pollution levels. Alternatively, the display can be changed to show social interactions at the bus stop – such as those generated by newly uploaded user-generated content. Some of that content could be provided via a system such as Yelp, an online city guide with reviews of local businesses and services in city neighbourhoods – all provided by the citizens (source: "Connected Sustainable Cities", and Osmose project RATP).

By displaying a lot of environment-related information, in real time, this approach can also be used as a instrument of direct awareness-raising about what is the potential impact of using a sustainable way of travelling.

4.3 Urban IT for better management

The overall presence of digital technology, internet and location-aware applications allows insights in data about city: road systems, buildings, people networks and use-patterns.

Sensors and smart devices collect meaningful data passively, increasing the information available on traffic congestion, carbon emissions, safety and security, etc. Combinations of commercial and government data ("urban informatics") gained this way allow powerful, new analysis which does not require much new technology to identify patterns not previously visible.

Urban informatics in mobility sector have shown great potentials, with improvement in signalling, location and positioning, monitoring of passenger flow and fuel and energy consumption. Urban informatics mean "Better information (real-time information), better access to information, and new ways of using the information (better decisions and solutions to problems)" (source: "Cities, Information, and Inclusion', *McKinsey and Company with support from with Rockefeller Foundatio*n).

Conclusions

Key findings

Chapter 01 Low carbon mobility and urban planning

Trends:

- Raising importance of non-motorised traffic as a part of urban interchange
- Mobility-on-demand
- Growing use of hybrid cars

Challenges:

- Adapting station surroundings, street network and parking spaces for non-motorized and hybrid ways of mobility
- Finding more direct routing to and from the station
- Creating the same spatial quality standards for all transportation modi

Opportunities:

- Redesign of excessive car infrastructure in the station surroundings
- Utilisation of changing mobility patterns of station users
- Innovative programming and more intensive land-use

Relevant questions for further consideration:

- Identification of (new) mobility lifestyles and their impact on the programme and space of the interchange
- New spatial typologies and conditions for mobility-on-demand in the station surroundings
- Identification of spaces that can be transformed to accommodate more non-motorized and clean fuel modi of transport (short term / long term)
- Stimulation of car-share concepts by urban design of the station surrounding

KEY FINDING

Chapter 02 Human programming and physical structure

Trends:

- Intuitive way-finding and improved information distribution
- Seamless connections between different modi
- Stimulation of natural assets at the station
- Integrated renewable energy sources in the building envelope
- Use of the combination of active and passive climate control systems
- Smart management of the station infrastructure

Challenges:

- Information overload
- Adaptation of sub-standard spaces of the station and the surroundings within existing boundaries / structures
- Perception of station and its surroundings as unsafe

Opportunities:

- Smart growth through flexibility: re-use of vacant spaces
- Refurbishment of the station and public space equipment

Relevant questions for further consideration:

- Identification of potential to establish different environmental zones within the station
- Possibilities for new station-related land-use, such as car-free housing in the vicinity, flextime working facilities in the station, new mixed-use developments
- Temporary use of the empty buildings or brown-field spaces, for commercial or community purposes

Chapter 03 Management tools

Trends:

- Interconnecting low-carbon practices between operators and service providers
- Implementation of clean fuel fleets
- Energy saving from operations and more recycling
- Smart grids

Challenges:

- Adapting for more waste-to-energy facilities within the station perimeters.
- Defying and implementing incentives for energy-efficiency
- Seamless ticketing or integrated ticketing, covering all the modi

Opportunities:

- Use of urban informatics for improving the management and operations
- Use of urban informatics to improve local conditions according to urban morphology, culture, and practice
- Including communities and citizens in finding carbon-minimizing solutions

Relevant questions for further consideration:

- What are the most evident barriers to more co-operation around low carbon issues and why do they persist?
- Balanced cost/revenue models
- ICT solutions compatible to local conditions

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