FONDATION TUCK
The Future of Energy

THE FUTURE OF ENERGY: LEADING THE CHANGE
A scientific program in support of a successful energy transition

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HUBS AND NEW MOBILITIES

REPORT SUMMARY

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The appendix to the Report Summary lists all of our source participants.

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REPORT SUMMARY

INTRODUCTION

Research goals

This research addresses the current major upheaval in mobility practices and its effects on urban organization and projects, especially hubs and exchange poles. Interchange, meaning the need to switch between different modes of travel during a journey, holds an essential place in it. Interchange is indeed the most dissuasive element in the use of public transport, as it entails loss of time, missed connections and discomfort associated with such changes.

At the core of our work is a reflection on the modalities of transfer. The goal of transforming the feeder-transfer experience into a continuous journey requires the conception of spaces capable of integrating all "new mobilities": new ways of *using* conventional or new vehicles, via any software device (all kinds of sharing: sharing the trip / sharing the car via a digital intermodality), or new ways of using private means of transport as public ones**;** and new types of *vehicles*, environmentally friendly and (generally) connected, autonomous or not, from one to four wheels.

The hub heralds the global evolution of sustainable movement in cities. In the society of exchange, the intermodality of modes of communication emerges as a decisive challenge in the conception of urban architectural projects.

The profusion of neologisms including the prefix « inter » attests to the current topicality of its meaning, with new words such as *intermodal* and *intermodality***,** *inter-connectivity* and *interconnected*, *interfaces*, *interlinkage*, *inter-flow*, *interoperability* as well as the notions of *seamless transfer*, cross modal and *multimodality* now sharing the lexical field with quasi-historic terms such as *exchange*, *interchange* and *interconnexion*. Current vocabulary may be less courteous: *interchange penalty*, *transfer barrier*, *break of load*...

Not all multimodal hubs are genuinely intermodal. "Intermodal", in fact, means more than just "interchange". Intermodality, in turn, includes any type of interconnexions.

A new mobility hub is a truly intermodal station where all services and functions, and all mobilities, traditional and « new », are clustered in/above/below/around/close to it.

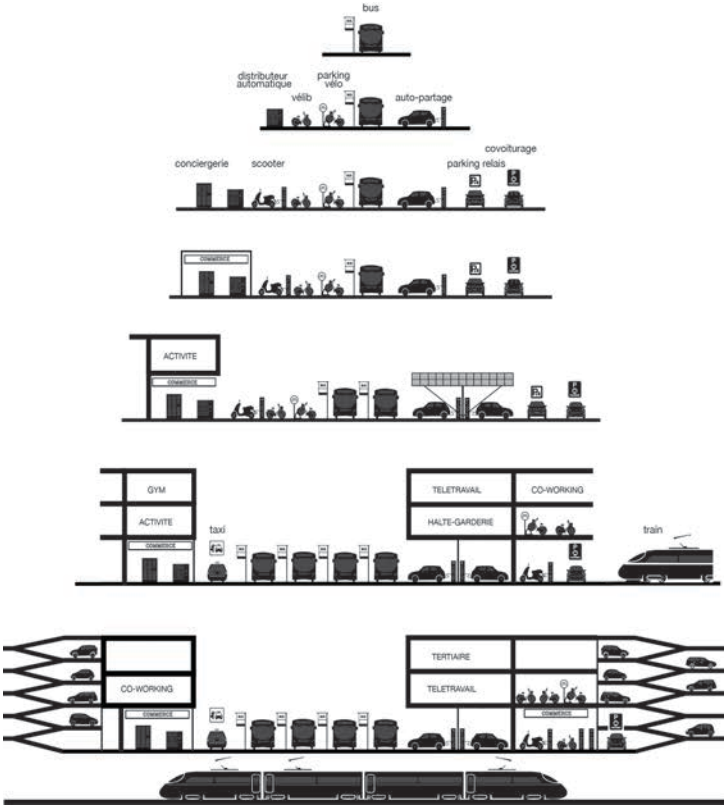
The hubs of the near future are new schemes in which accessibility and intermodality play a dominant role. Yet, we can still point out New York's Grand Central Station or La Defense in Paris as up-to-date hubs integrating most of the characteristics of contemporary developments.

La Défense, Paris (Photo © LIAT)

Spaces of Access

Car pooling in Brittany, near the exit of a 4-way road, 10 km from Saint-Brieuc. A possible forerunner of a Hub level 0?
(Ph. © LIAT)

The places of intermodality already identified in our *Door-to-door* research as "spaces of access" [1], can be of any scale and can accommodate every possible level of complexity, from the bus station to the feeder, from parking areas for car sharing services and electric vehicle charging stations that will gradually accommodate other transport modes and services, to the interregional and metropolitan hub or the higher-level airport hub.



The new hubs

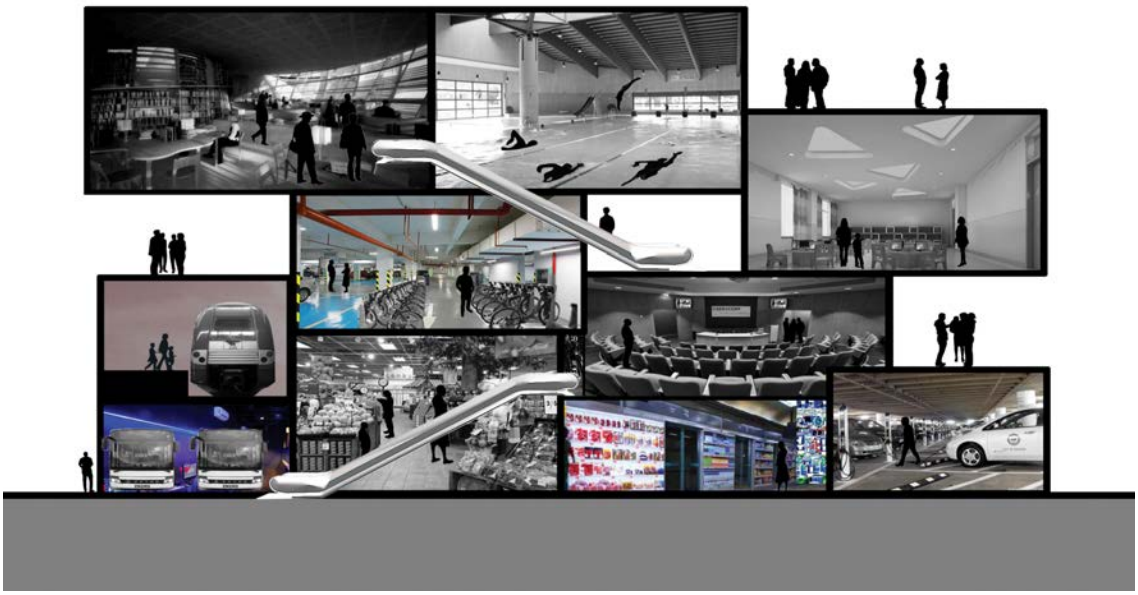
Level 1, 2, 3, and 4 hubs © LIAT

[1] This research relies on the first conclusions from our book Dominique Rouillard, Alain Guiheux, *Door-to door, Future of the vehicle, future of the city*, Paris, Archibooks, dec. 2015.

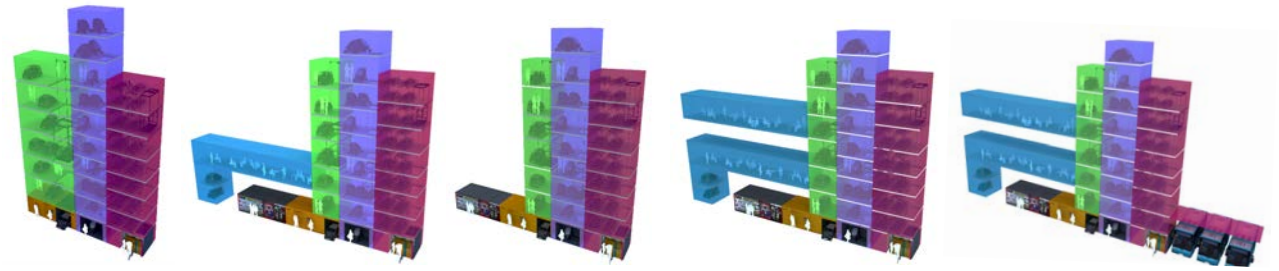
We consider **the growth of the hub** as the self-replicating mechanism of the dispenser principle: bicycle and car distributors, pickup points, virtual stores, co-working, teleworking and bus station, charging stations, etc.

Hub1: The high-end electric bus recharged at a station / Hub2 : the dispenser space, post office outlet, deliveries and bicycle- and car-sharing stations.

Hub3: General view of the installation of shops and convenience stores



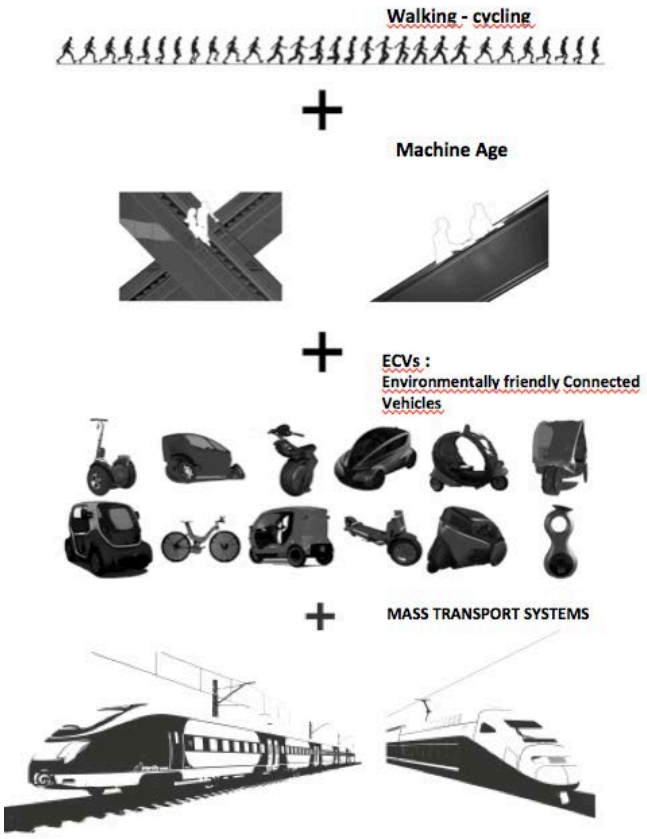
Hub4: Shift of activities to exchange poles © LIAT



The growth of hubs as general distributors: bicycle and car distributor, pickup points, virtual store, co-working, teleworking, and bus station © LIAT

All mobilities

Arguably, for some of the coming decades, no transport system will be in a position to singlehandedly become a complete substitute for the existing configuration(s). Consequently, it is the links, the articulations, the intermodality and the interoperability that need to be considered in the context of the multiplicity and totality of an individual's movements.



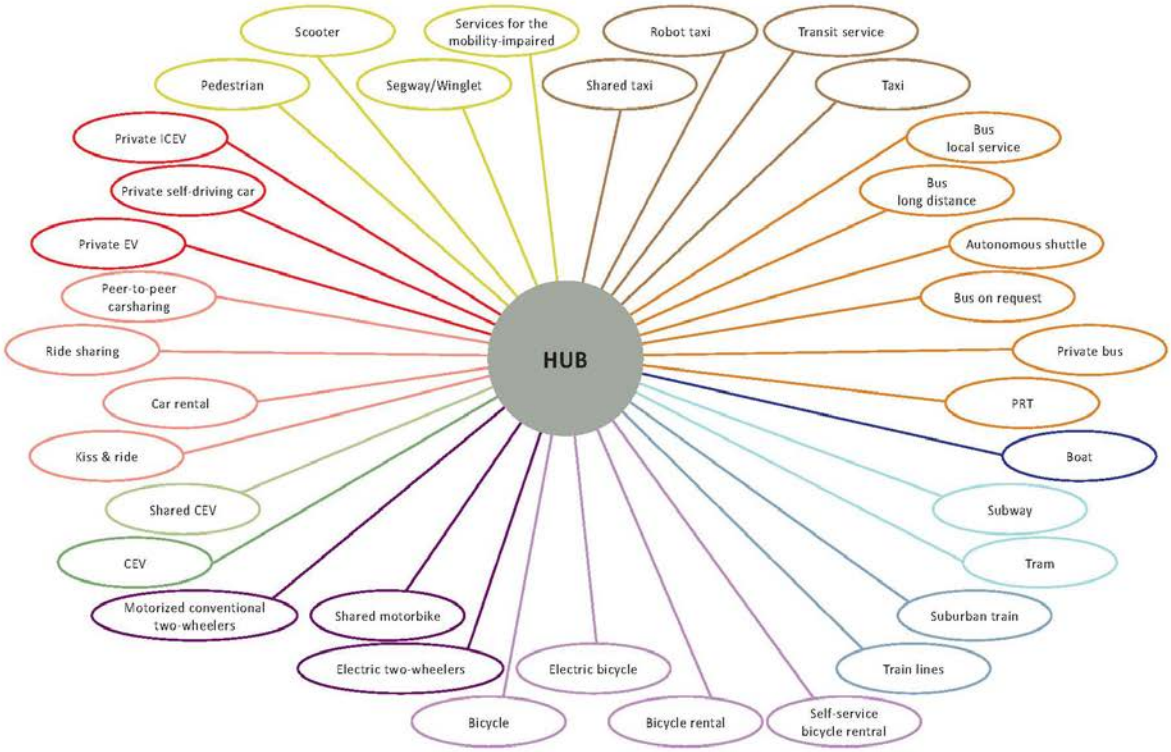
From walking to ECVs, conveyor belts or public transport: one single mobility universe © LIAT

Transport offers catering to those needs will become more and more available as a result of the combined demands of sustainable development and the digital economy. Our research found that hubs concentrate a wide variety of collective and individual travel modes:

Services for the mobility-impaired, shared taxi, transit service, taxi, robot taxi, bus, private bus, automated shuttle, self-service bicycle rental, bicycle rental, active bicycle, electrically-assisted bicycle, motorized conventional two-wheelers, electric two-wheelers, shared scooters, CEV (Communicating, Environmentally-friendly Vehicle), shared CEV, private car rental, ride sharing, peer-to-peer car sharing, private EV (electric vehicle), private self-driving car, private ICEV (internal combustion-engine vehicle), scooter, shared segway, solowheel, giropode, etc... and walking.

These travel modes range from “soft” mobilities, which call upon muscular power, such as walking and cycling, to those designed to assist the augmented human of the Machine Age: from moving walkways and escalators, to all the devices of individual urban ultra-mobility (one-, two-, three- or four-wheel CEV), public and shared personal transport, hybrid, electric and self-driving vehicles, and, of course, internal combustion vehicles (at least for a while) …

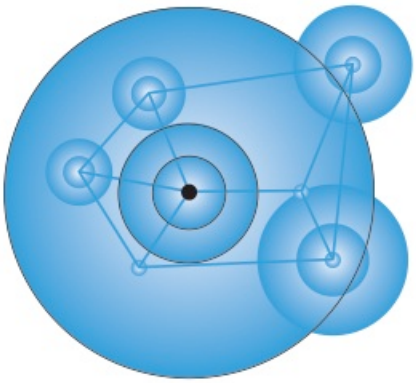
In the near future, over thirty different modes of transport and their different practices might coexist at hubs.



All the mobilities: More than 30 different modes of transport expected to coexist in future intermodal hubs © LIAT

These facilities bear a relationship with a variety of spaces and types of lanes for pedestrian and vehicle movements as well as for “traditional” *and “*new” mobilities, transfer spaces, waiting and parking areas, electric vehicle charging facilities, areas for provision of services. The hub hosts many new services and delivery activities as well as new forms of work and collaborative activities: entertainment, sport, shopping and retail, housing, etc. Together, they bring a new spatial complexity to all interchanges and hubs.

The advent of new modes and means of travelling produces a concentration and aggregation of mobilities and activities which are all attracted to each other by the cross-modal pole. This phenomenon of intense concentration, visible at increasingly attractive poles to the expense of less resilient ones which might eventually just wither, leads to a reinforced or reformulated polarization of urbanization which goes hand in hand with the development of an urban spread open by a greater accessibility. The opposite alternative, in which urban development concentrates on existing centers or on an accelerating dispersion of the spread city model, is rendered outdated by the hub's dynamic itself.



A pole more attractive than others © LIAT

Synthesis of initial hypotheses

Whether we focus on the analysis of European programs, on the experiences prompted by them, on the Grand Paris Express project or on ideas for reflecting on the definition of hubs following the advent of new mobilities, our research as a whole has been oriented and conducted on the basis of the initial hypotheses concerning several criteria:

Interchange: this is the most dissuasive factor in the use of public transport, as it entails loss of time, missed connections and the discomfort associated with such changes, which grows together with the proliferation of transport and transfer modes.

Urban planning: the Hub is a focal point in the development of urban agglomerations because it is the point of transfer and exchange of various mobilities as well as the location where most daily purchases are made and where work and other activities take place.

Distances and time distance: the vector of transport used to reach (or to leave) the hub is a key point. Its choice will depend on the distance between the point of departure and the hub, from the high-speed train to the ECV (and the other way around), between drop-off and boarding, and so on. This time distance will determine potential modifications in the transfer area.

Visibility: the availability of all modes of transfer, activities and services is as important as their easy visibility from inside the station space, within the overall ergonomics of exchange poles.

Parking facilities: they are transformed by the emergence of connected vehicles and self-driving cars with various levels of automation; a new form of drop-off is in sight here.

The public space: the blurring of limits between buildings and vehicles, pedestrians and the small, agile, silent and non-polluting ECV is typical of the new uses of the public space.

Reversal: it will no longer be the passenger who must walk, take the elevator, the ramp, the stairs or the corridors, but the car that will do it instead.

Multiprogramming as lifestyle: The switch in transportation modes during trips becomes an opportunity for doing other things. Multiprogramming has become a lifestyle. The multi-mobility services should be included in the generalization of multiprogramming and in the increase of service offers at the core of exchange hubs.

This research delivers:

1/ **an appraisal of European-funded actions** carried out from the 1990s to date, with a goal to develop expertise, knowledge and experience regarding interconnection and intermodality within hubs. Two lines of analysis were pursued: a) The integration of new mobilities in existing hubs, b) Their integration in future hub projects.

These approaches are accompanied by a **cartographic analysis of railway stations and other intermodal hubs** recently completed in fifteen European cities, with a focus on the existence and quality of the new mobilities offer, or on similar infrastructures which are currently in the process of being built (Greater Paris Express network).

2/ **thinking points and proposals** to be considered in the transformation of intermodal spaces and in the choice of typologies to be applied to the future hubs of new inter-mobilities. Here, our case studies of Japanese cities were decisive sources.

With the first goal in mind, we carried out a state of the art regarding projects that either are already completed, currently underway or projected for the near future. The intention of the survey was to establish a benchmark of the current knowledge in the field of intermodality spaces and, also, reaching further, of the "initiatives" undertaken by city administrations, companies and universities faced with the challenge of developing new environmentally-friendly mobilities. While the issue of intermodality and its spatial concerns has not always been on the agenda (in fact, rarely so), awareness of the "environmental urgency" is nevertheless real, and abundant are the means available to address it through transport and mobility solutions. We chose to collect and preserve this rich body of information, even though it was often provided by default, in a context where concrete solutions to the subject of intermodality are still to come.

As part of our research, around 70 reference institutions and individuals were contacted and interviewed on the site of their activity, in the various cities where our case study hubs were located[2]. We thus met with representatives of public and private transport companies, university research units focused on the future of mobility, applied research centres in the transport sector or others concerned with virtuous development in the field of transport, as well as with organizations and groups which are actively developing and promoting environmentally-friendly mobilities.

Our research did not undertake user surveys (the bottom-up perspective). We judged that existing scholarly work had already devoted considerable efforts, in terms of methodology and inquiry resources, with a goal to assess customers' perception of mobility services and possibilities for intermodal practice (*infra*, European-funded research).

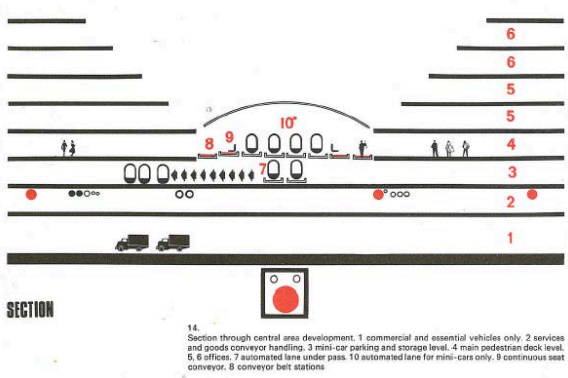
[2] . See contact list in the Annex.

I/ STATE OF THE ART AND CASE STUDIES

Reference documents were analysed in view of writing a state of the art and of defining the body of research. The main body of research is composed of projects funded by the European Framework Programmes for Research and Technological Development. Our interest in these was driven by the fact that several cities had recurrently featured as candidates for various European programmes. In the field of intermodality, for instance, Rotterdam and Utrecht lead the pack. They both participated in 'CIVITAS' and 'CITY HUB', and Utrecht was also a partner in 'NODES'.

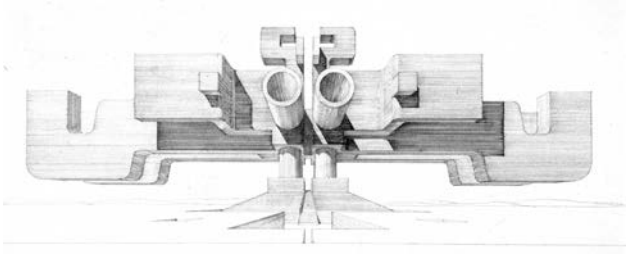
1. European research on intermodal mobility

Scientific literature shows that intermodality emerged in the context of the quest for alternatives to the use of internal combustion vehicles in the city. Signs of active thinking about multi-modal transport services can be traced back to as early as the 1970s, and even earlier in the field of architectural practice, as illustrated by Brian Richards' work in the mid-sixties. Richards re-launches the visions of the dense vertical city that were so prolific at the end of the XIX century, in which various circulation levels were laid one on top of the other. However, far from those utopic visions, his proposals in the form of schematic patterns, concentrate on the space of the interchange itself. He introduced automatic systems of transport - at the time somewhat experienced here and there, in Europe as in Japan - in which layers were added to the existing underground interchanges of mass public transport. The infrastructure supporting those automated systems remained a predominant figure contributing to the monumentality of the interchange.



Superposition of different means of transport with: (7) automated lane underpass, (10) automated lane for mini-cars only, (9) continuous seat conveyor. Brian Richards, *New movement in cities* (1966)

In the utopian/counter-utopian architects' vision of the same period, this monumentality is expressed through the reduction of the city to a single theme: the city as interchange.



Hans Hollein, Interchange City, 1965 © Hollein archives

Until the 1980s, the European Union funded separate research programmes, and no common framework existed. In 1984, during Étienne Davignon's tenure as European Commissioner for Industrial Affairs and Energy, research initiatives were combined in a single framework and the first Framework Programme for research funding was created[3]. **However, research efforts concerning the integration of a multiple offer of transport services did not gain ground until around the 1990s, and in some cases the 2000s**.

The first research project in the field of intermodal transport can be dated back to the late 1990s, in the context of the 4th European Framework Programme for Research, Technological development and Demonstration (FP4). Programmes such as HSR-COMET, PIRATE, GUIDE and MIMIC can be considered as pioneers.

• **HSR-Comet report** (*Intermodal Connection of **H**igh-**S**peed **R**ailway Terminals in Metropolitan Areas* - 1998): it identified the modal improvement to be realised. Only interconnexions between heavy transports were taken into account (metro, bus, taxi, regional train). And the improvements were not abundantly detailed. (Note: the idea to introduce an electric mini-bus service dedicated to HSR users).

Identification of the modal improvement realisations by priority

	Intermodal connection	*Influence factor*	*Improvement realisation*
1.	Metro	Safety	a. Employment of security guards
		Comfort	b. Supply of more comfortable HSR dedicated vehicles
		Flexibility	c. Increased frequency during HSR peak periods
2.	Bus	Travel time	a. Preferential lanes along the station access roads
			b. Reduction of transfer distance between bus stops and HSR platform
		Flexibility	c. Increased frequency during HSR peak periods
3.	Taxi	Cost	a. Tariff integration with joint ticketing
		Travel time	b. Realisation of preferential lanes along the roads of access to the station
			c. Reduction of transfer distance between taxi stops and HSR platform
4.	Regional train	Travel time	a. High level of intermodality at train station (parking, bus connections, etc.)
			b. correlation of train timetables with HSR
		Flexibility	c. Increased frequency during HSR peak periods
5.	HSR dedicated mode*		Introduction of new mode with tariff integration

*A suitable solution could be an electric mini-bus service (or other such taxi service with high capacity) dedicated to HSR user requirements (also open to other customers) offering tariff integration with HSR

HSR-Comet report indicators for modal improvement (1998)

[3] Ben Deighton, Peter O'Donnell, "Europe's Framework Programmes – a key element of research policy in Europe", *Horizon. The EU Research and Innovation Magazine*, 16 December 2014. Article published on the occasion of the 30th anniversary of Framework Programmes, accessible since 18 May 2016 on: http://horizon-magazine.eu/article/europe-s-framework-programmes-key-element-research-policy-europe_en.html

• **MIMIC** (***M**obility, **I**nter**M**odality and **I**nter**C**hanges* – 1998-1999): it identified passenger needs and priorities to build a framework for a structured evaluation of the necessary and desirable conditions to improve interchanges and intermodality[4]. The project was one of the first to use the notion of "**barriers to intermodality**" reported by passengers[5].

As early as 1999, almost all the barriers reported by passengers had been identified: the overall excessive walking distances between connections, the lack of comfortable waiting areas, the difficulty or even the impossibility for disabled people to gain access to train carriages, the insufficiently secure and weather-protected bicycle parking facilities, the absence of shops and other retail services available to commuters during waiting or transfer time, etc.

Typology of barriers	Main barriers	Sites	Users and Focus Groups	Key Actors
Logistical and operational	Poor or inappropriate funding from State and Local Authorities.	+		+
	Poor/lack of time synchronisation between services.	+		+
	Incomplete through-ticketing.	+	+	
	Queuing for tickets.	+	+	
	Insufficient number of ticketing machines.	+	+	
Psychological	Fear of physical attack and violence.	+++	+	+
	Thefts of cycles.	+	+	
	Thefts of cars and car radios.	+	+	
	Thefts and acts of vandalism to shops and retail activities.	+	+	
Institutional and organisational	Poor integration in planning and building interchanges.	+		+
	Poorly integrated interchange m anagement.	+++	+	+
	Competition on passengers and double services.	+		+
	Marketing opportunities often missed.	+		+
Physical design	Long distances to be walked between services.	++	+	
	Steps and staircases.	++	+	
	Lack of comfortable waiting areas and seating.	+	+	
	Toilets not properly maintained or not equipped for wheelchair users.	+	+	
	Poor cleanliness.	+	+	
	Lack of services for people working at the interchange.	+		+
	Access to vehicles for disabled persons.	+++	+	+
	Lack of reserved car spaces for the disabled.	+	+	
Local planning and land use	Pedestrian access over busy roads.	+	+	+
	Pedestrian access through unsafe areas.	++	+	+
	Lack of cycle lanes and/or cycle access over busy roads.	+++	+	+
	Lack of secure and covered cycle parking.	+++	+	+
	Poor public transport services feeding the interchange.	++	+	+
	Problems of dropping off and picking up passengers, with no provision in many cases.	+	+	+
	Lack of parking areas or insufficient car spaces.	++	+	+
	Lack of public consultation and participation.	++	+	+
Economic and social	Cost of public transport services.	+	+	
	If waiting times are short the opening of shops is not viable according to shopkeepers.	+	+	
	Lack of shops and retail activities.	++	+	+
Information	Lack of inform ation on routes and services.	++	+	+
	No integrated passenger information system.	+		+
	Real-time information lacking or available only for some transport modes.	++	+	+
	Staff not on hand to help passengers (both for information and personal security).	++	+	
	Lack of signing or signs of poor quality.	+	+	+
	Lack of acoustic signals and Braille maps for blind people.	++	+	+

'Sites': '+' if the barrier was cited at 3 sites or less;
'++' if the barrier was cited at 4 or 5 sites;
'+++' if the barrier was cited at 6 or more sites (up to 11).
'Key Actors': '+' if the barrier was cited at least by at least one key actor at one of the sites.
'Users & Focus Groups': '+' if the barrier has been cited by users or at least by a focus group at one of the sites.

"Main barriers": MIMIC Programme questionnaire example

Research published at the turn of the century demonstrates that most of transport professionals and urban planners had come to the conclusion that ensuring high performance of transport stops is essential if we want to change the modal split and reduce the negative effects of the massive use of personal motorized transport[6]. Guaranteeing that interchanges answer to the needs of users slowly became the subject of increasingly intensive evaluation efforts.

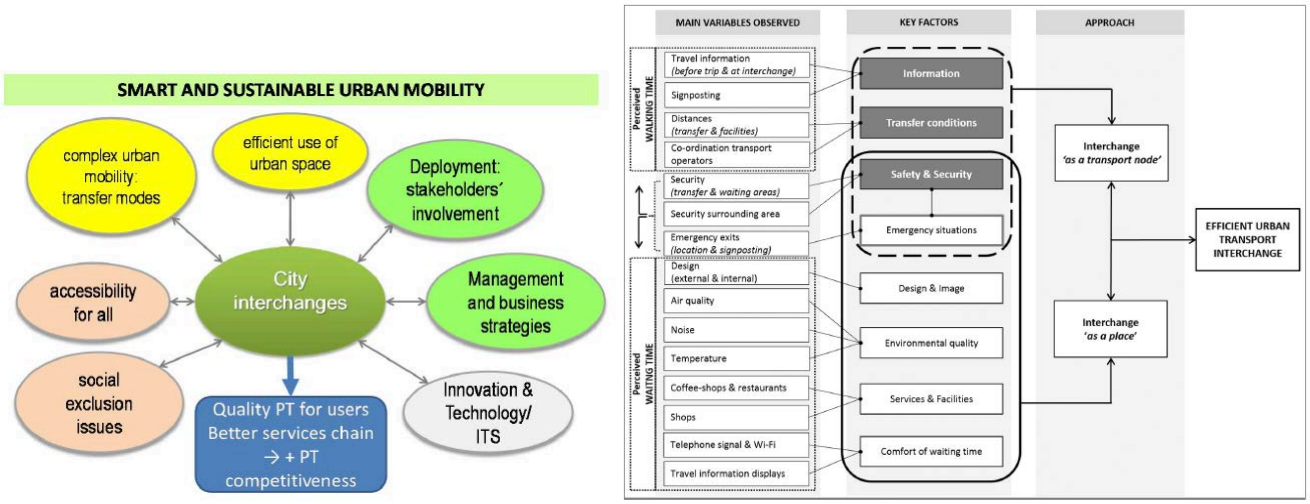
[4] Information from: Enzo Coccia, Paolo Delle Site, Francesco Filippi, Marco Lemessi, Antonio Mallamo, "Design of passenger interchanges" (not dated), presented in the framework of the 6th Thredbo International Conference on Competition and Ownership in Land Passenger Transport - http://www.thredbo-conference-series.org/downloads/thredbo6_papers/thredbo6-theme3-Coccia-Site-Filippi-Lemessi-Mallamo.pdf.

[5] See below our cartographic analyses of the MIMIC programme case studies (London, Rome, Tampere, Copenhagen, Bilbao, Warsaw).

[6] Sara Hernández, Andrés Monzón, Rocío de Oña (researchers involved in the City Hub project) refer to studies by such scholars as H. Iseki and B.D. Taylor (2010), as well as M. E. Lopez-Lambas and A. Monzon (2010), in: Sara Hernández, Andrés

• **CITY-HUB** project (*Innovative Design and Operation of New or Upgraded Efficient Urban Transport Interchanges* – 2012-2015): This is an illustrious example of an approach based on the measurement of user perception in the design City-Hub models[7].

Among the 37 observed variables in the City Hub project, "Safety & Security", "Information" and "Transfer conditions" are identified as « the most important factors in all case studies ». The benefits of interchanges mainly relate to time saving and better use of time. People may even accept to walk longer to an interchange depending on its aesthetics and the comfort conditions it offers.



Type of mapping for understanding hub complexity:
City-HUB vision of interchanges - Factors related to "interchange as a node" / "interchange as a place"

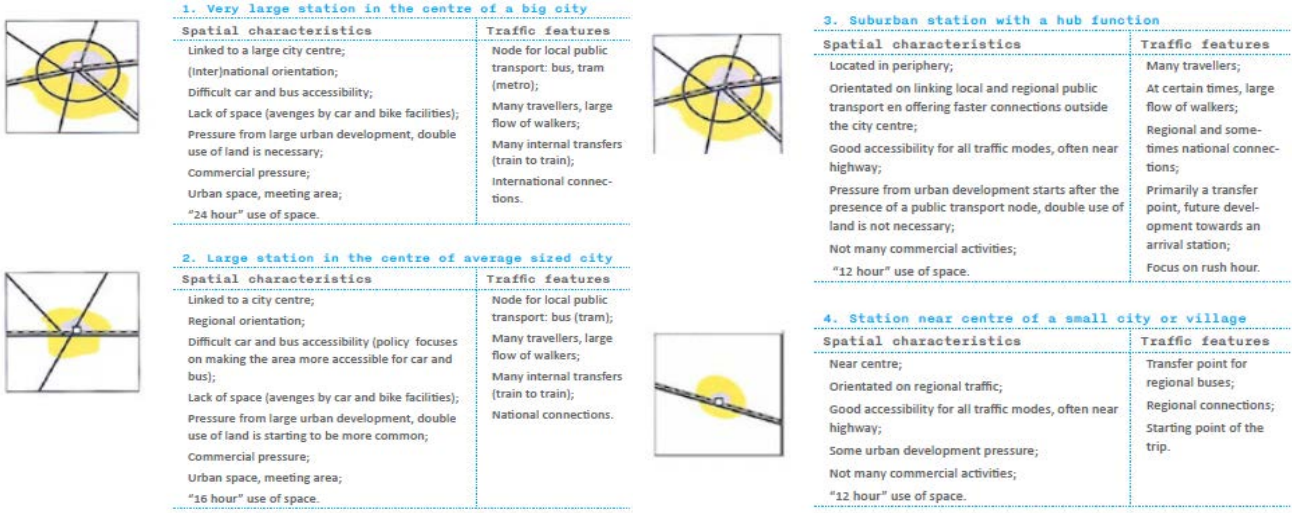
• Another EU project launched with the same aim to measure user experience, in this case through online surveys**: METPEX** (***ME****asurement* ***T****ool to determine the quality of* ***P****assenger* ***EX****perience* 2015 - 2016).

METPEX: Online participation call

Monzón, Rocío de Oña, « Urban transport interchanges: Importance-performance analysis for evaluation perceived quality », in: *Practical Applications of Novel Methodologies to Real Cases: Selected Papers from the XIII Pan-American Conference on Traffic and Transportation Engineering*, vol.84, February 2016, pp.31-43.

[7] *City-Hub Handbook. Innovative design and operation of new or upgraded efficient urban transport interchanges*, European Commission, Seventh Framework Cooperation Work Program, 16 March 2015. Responsible organization: Universidad Politécnica de Madrid.

• **NODES project** (***N**ew T**O**ols for **D**esign and Op**E**ration of Urban Transport Interchange**S*** – 2012- 2015): it featured a deliverable on the state of the art regarding intermodality. A total number of 18 European research projects were quoted[8]. NODES proposed a typological system for the classification of stations (developed by the Dutch Railway company Nederlandse Spoorwegen), from five topics intended to cover the key functions of an interchange (principles, tools, barriers, drivers, stakeholders).



1. Very large station in the centre of a big city

Spatial characteristics	Traffic features
Linked to a large city centre; (Inter)national orientation; Difficult car and bus accessibility; Lack of space (avenges by car and bike facilities); Pressure from large urban development, double use of land is necessary; Commercial pressure; Urban space, meeting area; "24 hour" use of space.	Node for local public transport: bus, tram (metro); Many travellers, large flow of walkers; Many internal transfers (train to train); International connections.

2. Large station in the centre of average sized city

Spatial characteristics	Traffic features
Linked to a city centre; Regional orientation; Difficult car and bus accessibility (policy focuses on making the area more accessible for car and bus); Lack of space (avenges by car and bike facilities); Pressure from large urban development, double use of land is starting to be more common; Commercial pressure; Urban space, meeting area; "16 hour" use of space.	Node for local public transport: bus (tram); Many travellers, large flow of walkers; Many internal transfers (train to train); National connections.

3. Suburban station with a hub function

Spatial characteristics	Traffic features
Located in periphery; Orientated on linking local and regional public transport en offering faster connections outside the city centre; Good accessibility for all traffic modes, often near highway; Pressure from urban development starts after the presence of a public transport node, double use of land is not necessary; Not many commercial activities; "12 hour" use of space.	Many travellers; At certain times, large flow of walkers; Regional and sometimes national connections; Primarily a transfer point, future development towards an arrival station; Focus on rush hour.

4. Station near centre of a small city or village

Spatial characteristics	Traffic features
Near centre; Orientated on regional traffic; Good accessibility for all traffic modes, often near highway; Some urban development pressure; Not many commercial activities; "12 hour" use of space.	Transfer point for regional buses; Regional connections; Starting point of the trip.

Nodes project, typological system: 6 typologies, 12 criteria, 2 different themes**: Micro accessibility and Macro accessibility**
(©Frank van der Hoeven and al., *Nodes Report* May, 30 2013)

While the European Commission had acknowledged this quite early on, concrete efforts to integrate these "new" understandings into urban mobility policy only began in the late 2000s, with the publication of such documents as the *Green Paper towards a New Culture for Urban Mobility* (2007) and the *Action Plan on Urban Mobility* (2009)[9].

Around the mid-2000s, reflection on intermodality was articulated more closely in reference to specific urban spaces, either designed from scratch or gradually refurbished ones, to enable the interchange function as well as many other urban activities relevant to enhancing the value of waiting time.

LAST EU PROJECTS LAUNCHED

Smart, green and integrated transport - FP8 EU Programme: H2020

The H2020 European Programme shows that attitudes have evolved on the subject of "**Smart mobility in cities**"[10]. In updated and increasingly shared terms, it was announced that: 1/ « This challenge is aimed at achieving a European transport system that is **resilient, resource-efficient, climate and environmentally friendly, safe and seamless** for the benefit of all citizens, the economy and society » ;

[8] Frank van der Hoeven, Akkelies van Nes, Stefan van der Spek, et al., *State of the Art*, NODES Consortium, 01.05.2013.
[9] Green Paper "Towards a New Culture for Urban Mobilty":
https://ec.europa.eu/transport/themes/urban/urban_mobility/green_paper_en
Action Plan on Urban Mobilty:
https://ec.europa.eu/transport/sites/transport/files/themes/urban/urban_mobility/doc/2010_06_24_apum_council_conclusions.pdf. See also: Frank van der Hoeven et al., "New tools for design and operation of urban transport interchange facilities, zones and development areas", in: *Proceedings of the symposium Transport Research Arena 2014*, Paris, 2014.
[10] Smart, Green and Integrated Transport - FP8 EU Program: H2020: 2 programs: 2014-2015 + 2016-2017.

2/ The Intelligent Transport System is one of the essential elements **for making mobility as a service become a reality**, **by connecting all elements of the multimodal transport system** – travelers, goods, vehicles, information and communication technologies and infrastructures.

Similarly, an indicator of change appears through the addition of a new approach to the usage perspective, which raises questions about the travel mode itself and as to whether innovation might not come (also) from the vehicle used for transfer from one mode to another (« Bike Intermodal »). A shift in attitudes that echoes our line of thinking about "inversed mobility" (*infra*).

H2020, 2015: Bike Intermodal (©Alessandro Belli of Tecnologie Urbane, Italy).

• Research carried out in the field of airport intermodality must also be taken into account, as multimodality is already present in the airport environment where "new mobilities" are more effectively integrated into the overall concept.

The **DORA PROJECT'S CHALLENGE (*Do**or to door information system for **A**irports* – 2015-2018) integrates all modes into one information platform, thus reducing travel time as well as the amount of energy wasted due to unnecessary travel time.

Development of software-based solutions for seamless travel. The service will be enabled by a single smartphone application and Internet website (Tegel Airport in Berlin and Palma de Mallorca Airport). (©Michael Abraham, Berlin University of Technology, 2016).

List of the EU researches (1996 – 2017)

HSR-COMET: *Intermodal Connection of High-Speed Railway Terminals in Metropolitan Areas* (01.1996 – 03.1997).
PIRATE: *Promoting Interchange Rationale, Accessibility and Transfer Efficiency* (01.1998 – 06.1999).
GUIDE: *Group for Urban Interchanges Development and Evaluation (*1998-2000).
MIMIC: *Mobility, Intermodality and Interchanges* (01-1998 – 06.1999)
EU-SPIRIT: European System for Passenger Services with Intermodal Reservation, Information and Ticketing- (12.1998 - 03.2001)
INTERCEPT: Intermodal Concepts in European Passenger Transport (12.1998 – 11.2000)
SWITCH: Sustainable Workable Intermodal Transport Choices (1999-2000)
CIVITAS: Cleaner and better transport in cities: (2002 – 2012) (58 partnering cities).
KITE: Knowledge base for Intermodal Passenger Travel in Europe (2007-2009)
Trendy Travel: Make sustainable transport modes such as walking, cycling and public transport more attractive (2007 – 2010)
LINK: European forum on intermodal passenger travel (04.2007 – 03.2010).
MEDIATE: Methodology for Describing the Accessibility of Transport in Europe (12.2008 – 11.2010)
NICHES+: New and Innovative Concepts for Helping European transport Sustainability towards implementation (2008 – 2011).
EBSF: European Bus System of the Future (2008 - 2012).
ORIGAMI: Optimal Regulation and Infrastructure for Ground, Air and Maritime Interfaces (02.2011 - 04.2013).
CLOSER: Connecting Long and Short-distance networks for Efficient Transport (2010 – 2012).
CITY-HUB: Innovative Design and Operation of New or Upgraded Efficient Urban Transport Interchanges (09.2012 – 02.2015)
NODES: New Tools for Design and Operation of Urban Transport Interchanges (oct. 2012- sept. 2015).
METPEX: Measurement Tool to determine the quality of Passenger Experience (2015- 2016)
SMART, GREEN AND INTEGRATED TRANSPORT - FP8 EU Programme: H2020: 2 programmes: 2014-2015 + 2016-2017
BIKE INTERMODAL (2014)
The DORA project's challenge: Door to door information system for Airports (2015-2018).

MIMIC, CIVITAS, CITY-HUB, NODES

45 European cities engaged in 4 EU research programmes on intermodality issues: MIMIC, CIVITAS, NODES, CITY-HUB (1998-2015) © map LIAT

CONCLUSION OF EU RESEARCH PROJECTS

The projects funded by the European Framework Programmes for Research and Technological Development reveal significant awareness of problems inherent to interconnectivity and of the increasingly urgent need to achieve efficient intermodality. Since the 1990s, around twenty different research initiatives have been led by numerous players – academic institutions, townhalls, consulting firms, industrial corporations, and even citizen associations.

Most points of view are represented in such initiatives, and the problems related to the nefarious effects on health have been identified – air and noise pollution, effects on air quality and human health, vehicle noise emissions. Solutions invariably turn around the measures to be taken; pedestrianization, restricted access zones, speed limits, urban charging, safe infrastructure for walking, cycling and private vehicle use, etc.). Intermodality and interoperability depend on the improvement of links among public transports interconnected with national long-distance networks and the Trans-European Networks, but also on promoting "the rational use of private vehicles in cities and metropolitan areas, for example through carpooling, car-sharing and park and ride facilities". The researches led to the creation of facilities for improved multimodal travel (for instance, bicycle parking units and the so-called park & ride facilities),

and set the standard for real-time data communication to users. The various proposed toolboxes range from those whose goal is to ease interconnections and make the best of them in future hub projects, or improve existing ones, to the integration of hubs as economic and commercial drivers in ambitious urban projects, all driven by energy-efficient and environmentally friendly goals, with the support of Information and Communication Technologies.

However, our analysis of European-funded research actions and case study hubs (whether recently completed or currently underway) demonstrates that conclusions remain at the level of generic recommendations and are essentially centered on interconnections among public transports in the traditional sense (inter-regional, interstate, etc.), and on the promotion of soft means of movement (walking and cycling) and the sharing of private vehicles (car sharing, car pooling, park and ride). Even after admitting that " Society is changing, and is expecting more intelligent and affordable mobility solutions " the ways in which the ITS could expand awareness beyond the macro infrastructural scope are rarely highlighted. Thus, the multiplicity of new mobility practices as well as the new modes of transport and the spaces devoted to them have not been sufficiently taken into account.

We argue that the way research activities have been framed, to this day, has largely contributed to this oversight:

- **Methodology has not been sufficiently updated to fit contemporary contexts, problem issues and social configurations**:
  - Inquiries have mainly taken the form of user surveys;
  - Users concerned by new and still marginal practices have insufficiently been taken into account;
  - Analysis has been based on existing conditions of travel in existing stations;
  - Research teams dealing with the same topic have not communicated thoroughly enough nor carried their missions in sufficiently competitive environments to achieve complementary results.
- **Aims and deliverables have not always been consistent**:
  - The goal to measure and to evaluate has been the driver of research;
  - The overriding concern to find a common European-wide standard has led to a reduction of complexity and local specificities;
  - There has been delay in seriously taking into account the last mile issue;
  - Prospective research and ground-breaking solutions are still lacking;
  - Insufficient attention has been paid to architectural and urban design, and to the role of spatial organization.
- **Researches have been excessively dominated by, and driven towards, engineering concerns.**
  - Research has been mostly carried out by transport scholars and engineers;
  - The development of software-based solutions for seamless travel has failed to consider the spatial dimension and the complexity of interoperability;
  - The focus has concentrated on the interchange function within railway and underground systems;
  - Research has lacked a multidisciplinary approach (sociologists were often the sole representatives of human science disciplines, as they were called to the rescue by engineers, especially in the case of user experience evaluation).

None of the European-funded projects has been fully devoted to depicting the relationship between spatial layouts and the performance (and perception) of the interchange.

2. RECENTLY COMPLETED STATIONS AND ONGOING EXPERIMENTS. A comparative analysis of the current state of intermodality in European cities.

In view of obtaining trustworthy data and of experiencing infrastructural projects, we visited the sites of representative case-studies. While some of the data had been collected beforehand, interviews with transport authorities, townhall officers and project leaders were carried out on-site.

All in all, 20 case study hubs of varying scales were chosen among the five European countries that are currently at the forefront of the installation of new mobilities. Some have participated in European-funded research, while others have not. Our choice of a rather heterogeneous set of cases was deliberately based on a desire to understand whether a significant difference in the development of intermodality and new mobility exists between the perspective of European institutions, on the one hand, and that of national, regional and municipal institutions, on the other.

The 20 case studies of European hubs were also graphically analysed, highlighting the maximum, real multimodal offer in its current form (2017) in and around those hubs, and identifying the parking areas and the charging points of “traditional” and “new” mobilities. The graphic measure used is time distance (5 min per approximately 300 m).

The time distance for each change in mode of transport is intermodality’s efficiency and comfort criterion. This variable is measured on our cartographies.

The 20 case study interchanges were mapped and analysed in view of highlighting two aspects: 1/ the traditional, conventional mobility offers, and 2/ the new mobility offers.

A series of maps and diagrams show the proximity of access to such services:

- **a mapping card showing all transport offers in the proximity of the station**, within a 3 to 4 km perimeter;

- a diagram comparing the time distances to be covered with a reference walking time distance of 5 minutes (corresponding to a distance of approximately 300 meters), to link the theoretical point of the heart of the station and the transport offers (traditional and new ones).

- **two separate time distance cards** with the same time distance indicator: one showing the time distances to the access to traditional mobilities, and another one showing the time distances to the access to new mobilities.

It cannot be denied that, whether supported or not by the funds of the European Commission, refurbished stations still take little account of new mobilities; when they exist, in the form of bicycles or shared cars, whether electric or not, their access remains more difficult or more distant than that proposed for traditional modes. This remoteness can be justified in cases of redevelopment of existing "historic" stations, where traditional mobilities pre-exist and thus new parking spaces or access points to shared services will always be located farther away from the heart of the station. However, in situations less bound by historical constraints, this sequence of development still persists and appears hard to dislodge, as the understanding of new mobilities and the multiplicity of vehicles and modes soon to be expected to interfere is slow to make its way into the conscience of the developers.

TWENTY SELECTED CASE STUDIES:

Two categories of interchanges were selected; our goal was to analyse their intermodal performance (refer to the graphic analysis report).

1/ Stations where the issue of interchange has been backed by the MIMIC project (1998-1999):

London: Stratford (station redevelopment project to prepare for the Olympic Games of 2012).
Rome: Ponte Mammolo (redevelopment of an existing bus interchange, built in 1996).
Tampere: Tampere Intermodal Passenger Terminal (redeveloped in 2014-16).
Copenhagen: Valby Hub (recently redeveloped interchange, 2010-2012).
Bilbao: Bilbao Central station (1999- redeveloped in 2006) + Bilbao Termibús Abando (1996-2015).
Warsaw: Wilanowska/Pulawska (existing hub, planned to be redeveloped, 1999).

• **Stations that were part of the NODES and CITY HUB case studies, and/or stations that were selected due to their involvement in the CIVITAS initiative (as part of work packages dealing with intermodality)**[11].

Twelve case study sites were selected in the following cities:

The Netherlands: Amsterdam, Rotterdam, Utrecht, La Hague, Hertogenbosch.
Germany: Bremen, Berlin (Sudkreuz Station + INNOZ EUREF).
Sweden: Gothenburg (Central station + Stenpiren travel centre).
France: Grenoble, La Rochelle (Central station + Verdun square).

In this summary of our Research, we introduce some examples of hub analysis (in blue).

THE NETHERLANDS

The most important transformation of railway stations in the Netherlands was triggered by the introduction of high speed train lines that would improve links between Dutch and European cities. Interconnection between other modes of public transport has since become even more crucial. Thus, the Dutch railway stations have benefited the most from the European research funds for redevelopment, through the programs Nodes, Hub, Civitas and H2020.

This new European connection also involves, particularly in the case of the central station of Rotterdam, the search for a recognizable international image of "the station" (in line with the model of those of Paris and London in the 19th century[12]). The question of the "new mobilities" was therefore secondary in the restructuring projects, or even non-existent, considering, on the one hand, the launch date of the projects (for the Dutch central stations: Amsterdam CS, 1999, Rotterdam CS, 2003, La Hague CS, 2002) and, on the other, the massive use of the bicycle, a mobility practice which, if not new, is nevertheless *already* ecological. In this context, it is no wonder that new services and innovative modes of travel should be scattered all around the station area. This statement is true for all cases studies, even if national and local singularities do exist.

[11] Grenoble was the sole exception: while the city's central station has not been part of European projects, the Townhall is currently the sole European partner of the Toyota car manufacturing company for the development of their intermodal mobility concept 'Ha:mo'. See below.

[12] Interview of Jan Benthem, architect, founder of the architectural and urban design firm Benthem Crouwel Architects (18 March 2016). This agency has led all the major restructuring projects of the Dutch central stations selected in this study: Amsterdam, Rotterdam, Utrecht and The Hague.

The key question in Dutch transport undeniably concerns the challenge of where to park everyone's bike. One might even wonder if one strategy in terms of travel would not consist in deterring the Dutch from using their personal bikes, so as to push them to agree to sharing them or to using the traditional public transport widely available to them (particularly the tram). But the Dutch, who are proud to own several bikes for specific uses, and for whom cycling in an integral part of their life ethics refused to pay the parking fees planned by the authorities for some of the 5000 bike parking spaces provided under the forecourt of Rotterdam CS station[13].

Otherwise, the Dutch have long ago integrated the logic of door-to-door travel, using the bike as the only acceptable option to reach a fast mass means of transport. Another consequence of this particular relationship to the traditional bicycle might be the relative delay of the Dutch industry in the development of the electric bicycle technology.

In all situations, excess bicycles remain a major part of the challenges concerning the parking and the interconnection in railway stations. In Amsterdam CS, the redevelopment project facilitates both the connection with the river transport for bicycles (proximity and direct access to the ferry station) and with the bus (building of an elevated bus station).

The Dutch State has played an important role in **facilitating the deployment of environmentally-friendly vehicles and shared mobility services.** In most cities, private and public players have implemented electric vehicle charging bays, thus making the Netherlands one of the most well-equipped countries on this count. Inside intermodal hubs, however, access to electric charging infrastructure is not yet provided, neither is information on this kind of infrastructure, even though, often, charging bays are located in the larger station area. The problem of integrating new mobilities remains, even in hubs that were recently designed or are currently being built.

On the side of shared mobility services, the Netherlands is again an interesting case. Most of Dutch car sharing companies provide a station-based, easily identifiable service, offering access to shared vehicles in city centres as well as in the suburbs. Due to the lack of space and stable contractual relations, car sharing services are not integrated in the station design process. Instead, they follow a dynamic of their own.

The Dutch railway company **Nederlandse Spoorwegen** (NS) has also been an active partner in shared mobility development. The NS created its own bicycle sharing scheme, the 'OV-fiets' (*Openbaar Vervoer – fiets*, meaning "exchange from public transit to cycling") in 2003. Today, this scheme is present in many central railway stations across The Netherlands. In the stations we visited, shared bicycle services are provided either on the station square or inside an underground facility very close to the station.

In parallel with the redevelopment projects of the country's main railway stations, the State, regions and universities, as well as private and public investors, are particularly active in developing and promoting the "national drive" towards "intelligent mobility systems".

We will mention, among other projects, **De Verkeersonderneming** (Traffic Management Company), an intermediary organisation fostering cooperation between the public and private sector around urban mobility, created in 2008 by the regional authority of Rotterdam, the Port and the Ministry of Infrastructures and the Environment (DV). The DV started working to change the demand for mobility, offering alternative means of transport such as bicycles, e-bicycles, and e-scooters, as well as the "**Avoid Rush Hour"** program. This includes: - the '**Beter Benutten**' program, which aims to make better

[13] Interview of Jeroen van den Heijden**:** business asset manager at Nederlandse Spoorwegen (22 March 2016)

use of existing infrastructures ('Better Use' or 'Optimising Use'); - the **"Marketplace for mobility**" program, conceived to help all companies find clients for their products or mobility services (27 different products/services identified); - the **low emission zone** for the new port area (2016) ; - the proposition for **cross-modal hub development in Rotterdam**, an integrated vision for spatial planning and infrastructural development by 2040 (MUST consultancy firm, 2009, not yet approved).

The 'Congestion wilder beast' campaign: encourage citizens, employees and employers to avoid travelling during congestion hours © De Verkeersonderneming, 2008

Interchange development in Rotterdam by 2040. © MUST Consulting, 2009.

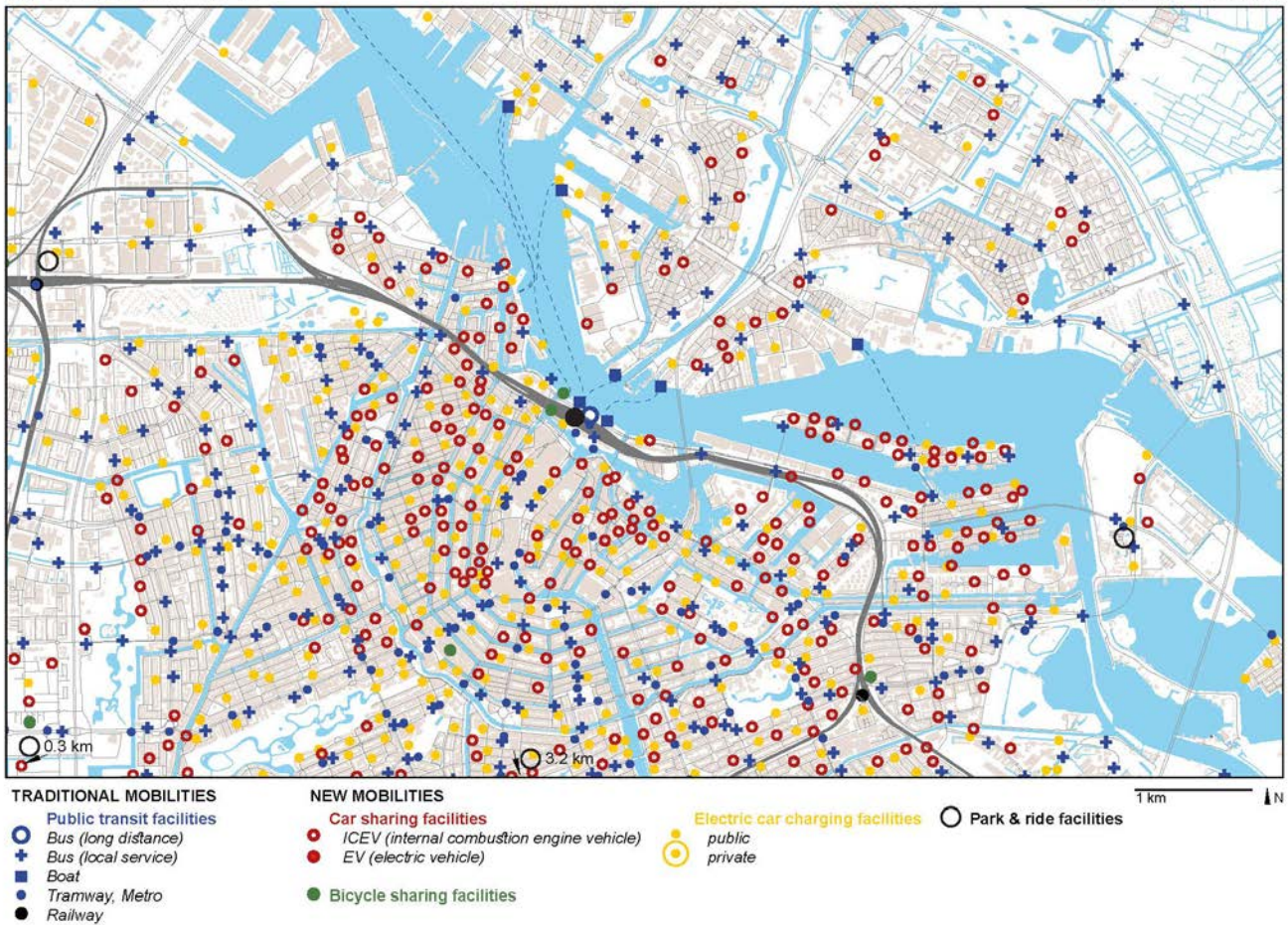
• AMSTERDAM CENTRAL RAILWAY STATION 1999-2004-2017

European Structural and Investment Funds + H2020

Amsterdam is said to have the densest charging infrastructure in the world. In 2014, the city passed the milestone of 1000 public charging stations (mainly for plug-in hybrid electric vehicles), and the aim is to have 4000 charging stations in the city by 2018. There is also growing interest in electric bicycle ownership (with purchase numbers doubling since 2014)[14].

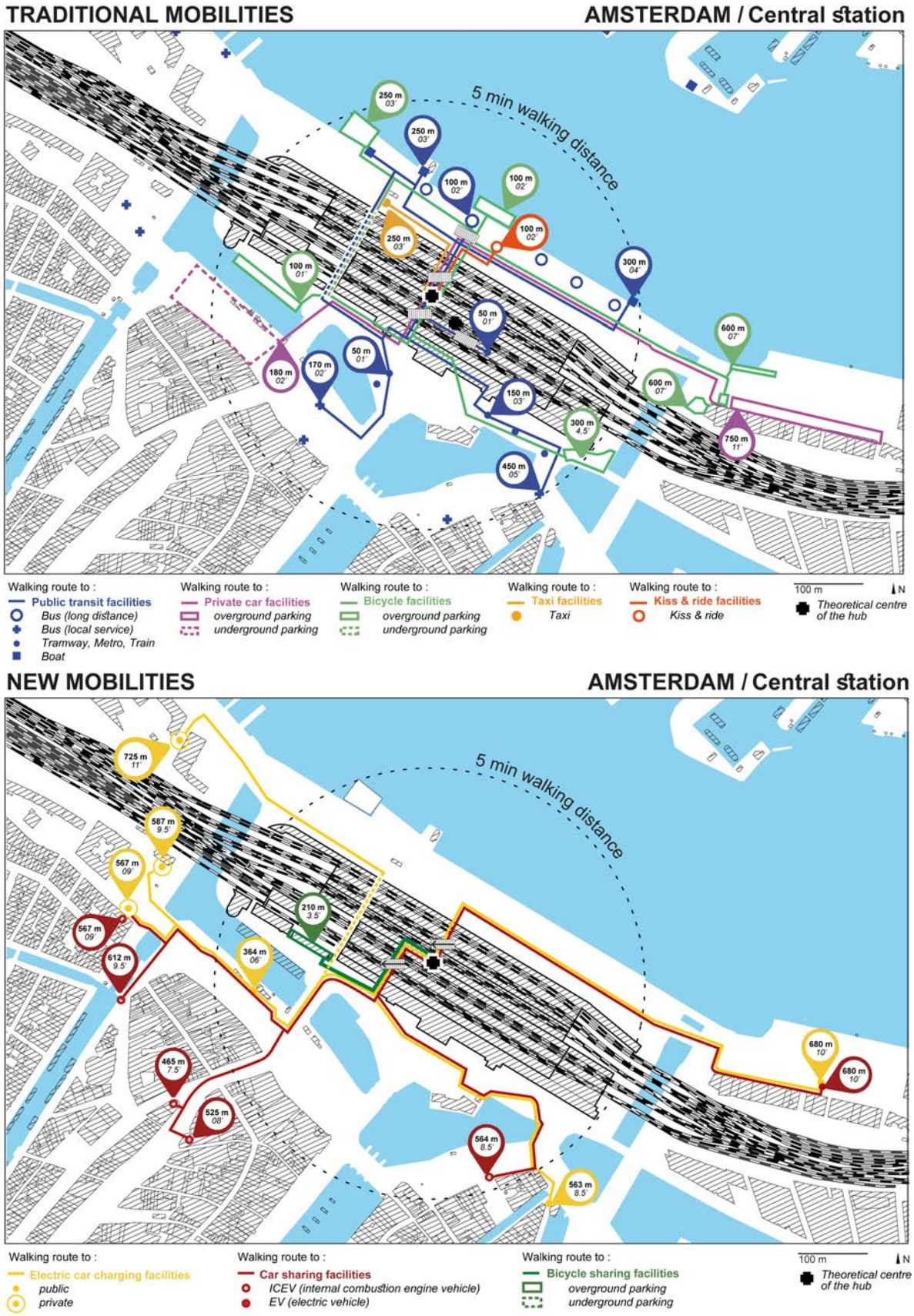
Our research found that the city offers a rich infrastructure of bicycle parking facilities: there are around 25 000 racks in public spaces near the central station, among which 13 000 are publicly- and privately-owned, low-fare, supervised storage units, and 4000 are free-of-charge municipal supervised storage units. In addition, several hundred parking spaces are provided on boats, which are docked along the Amstel river bank on the back side of the central station.

However, and despite European support, new mobilities remain scattered around the Central Station area, further from the traveler than conventional services, and, all in all, bicycle parking facilities are rarely sheltered and remain located outside the station building.

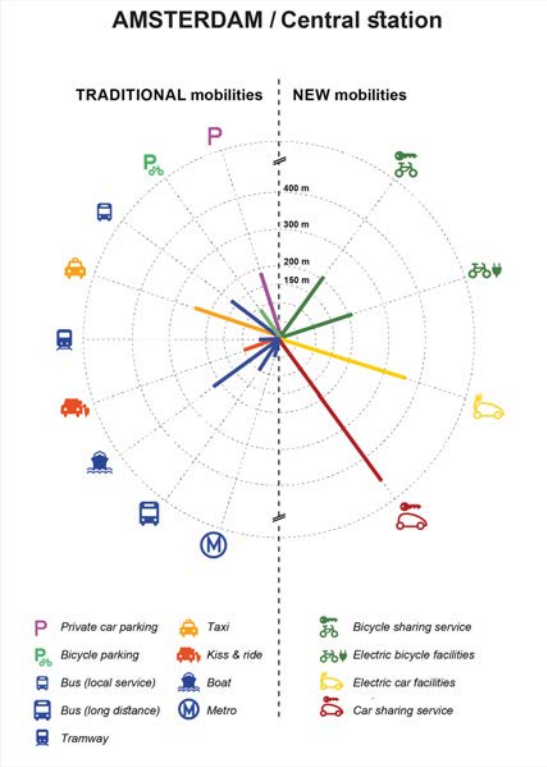


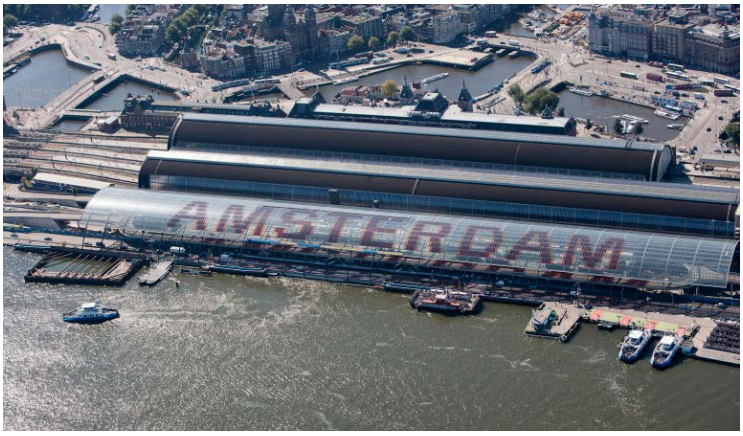
Mapping of all transport offers close to Amsterdam Central Station © carte LIAT

[14] Cycling: 32% of traffic and 48% in the inner city; 800 000 cycles; 35 bike rentals companies. "Cycling facts and figures", column published on the Amsterdam city's website "I Amsterdam": http://www.iamsterdam.com/en/media-centre/city-hall/dossier-cycling/cycling-facts-and-figures (accessed on 23 November 2016).



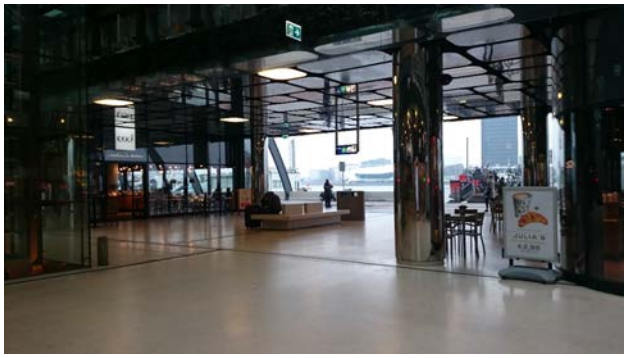
Comparison of time distances to accessing traditional (up) and new (down) mobilities © LIAT



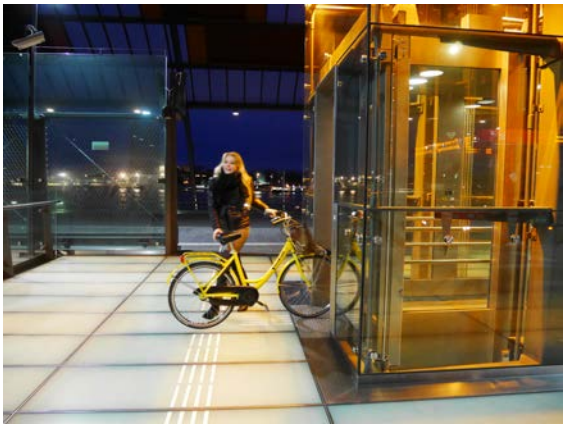


Amsterdam CS refurbished by Benthem Crouwel Arch. (1999- 2017): opening on the water front, multi-modal station complex for train, bus, metro and water transport. Ph © Benthem Crouwel

Diagram of time distances for reaching traditional and new mobilities from the heart of the station with a reference walking time distance of 5 min (about 300 m) © Liat



Amsterdam CS: waiting and shopping area with a view on the river bank / Escalators from the ground floor shopping and transit area to the bus terminal on the first floor. © Ph. LIAT



Escaltor and lift to the bus terminal © Ph. LIAT

Elevated bus terminal under the dome of Amsterdam CS

Bus at upper level, bicyle lanes and ferries © Ph. LIAT

A 130 m tunnel for pedestrians and cyclists running through Amsterdam CS to connect the city centre and the water front and ferries . View from the city center (left) , view from the river (right) © Ph. LIAT

Ferry station, located next and linked to Amsterdam CS - One of the boats converted into a bicycle parking space © Ph. LIAT

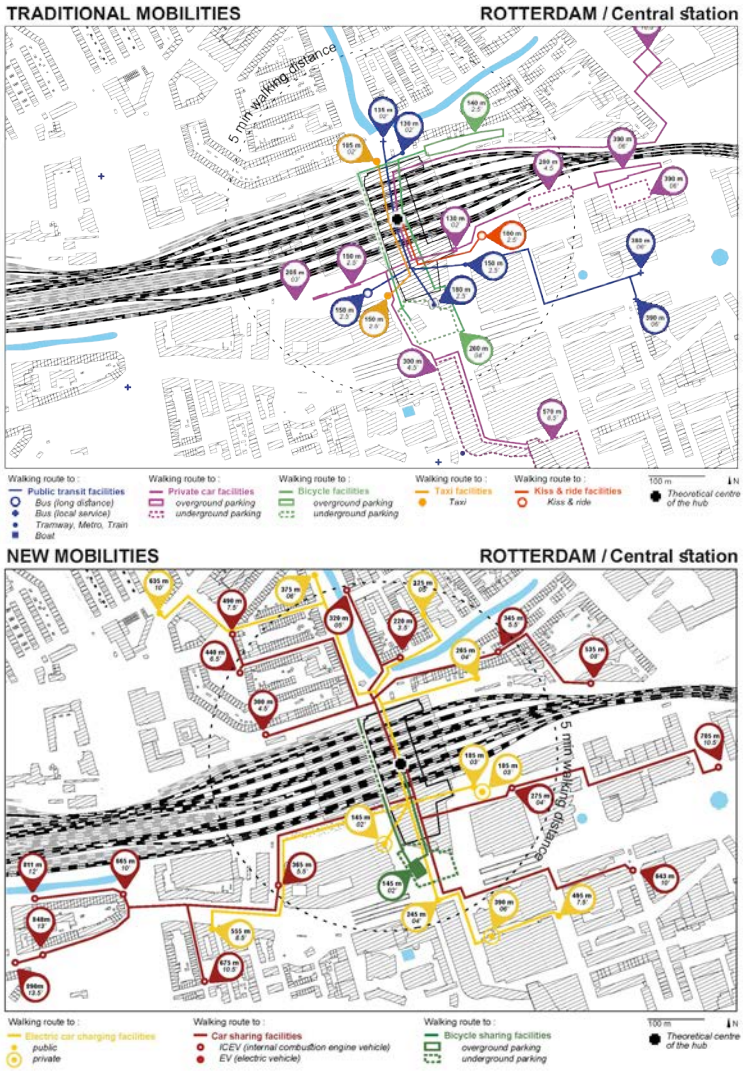
ROTTERDAM INTERCHANGE REDEVELOPMENT PROJECT (2003 – 2014)

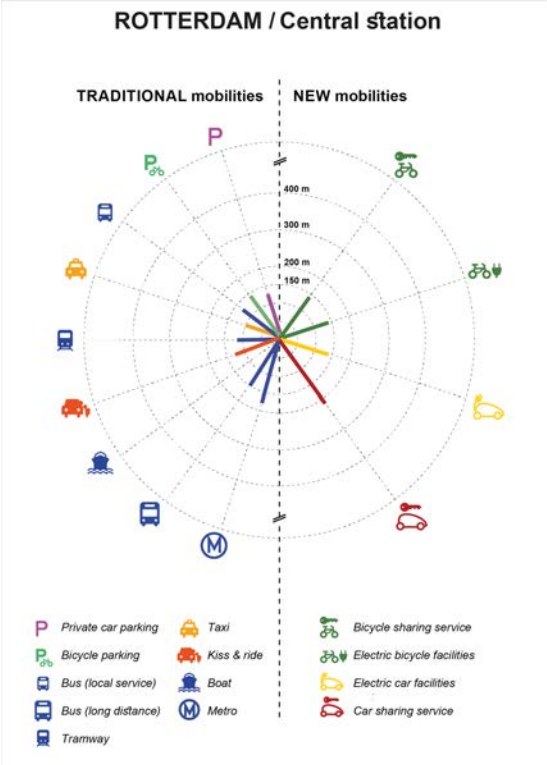
CIVITAS (2002-2006: improvement of the last kilometer transport via an autonomous shuttle: Kralingse Zoom station) + NODES (2012-2015).

The aim was to convert the central railway station into an international one with an internationally recognizable image, as Rotterdam central station is considered a showcase for people arriving from countries such as France. While the old station was designed for easy car access, the redevelopment project aimed, on the contrary, to free up space for pedestrians and public transport.

The new station was programmed to offer a new, spacious and efficient terminal building enhancing the high-speed railway link to Europe and connections via the metro system, a new bus station, a new underground bicycle storage facility (5 200 units) under the forecourt, a parking area near the station (five story carpark, room for 760 cars).

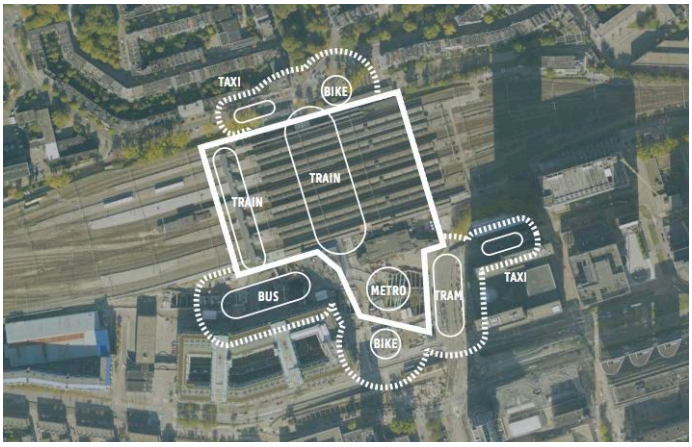
Solar panels (10 000 m²) covered a third of the total 28 000 m² roof surface, making it Europe's largest photovoltaic roof.



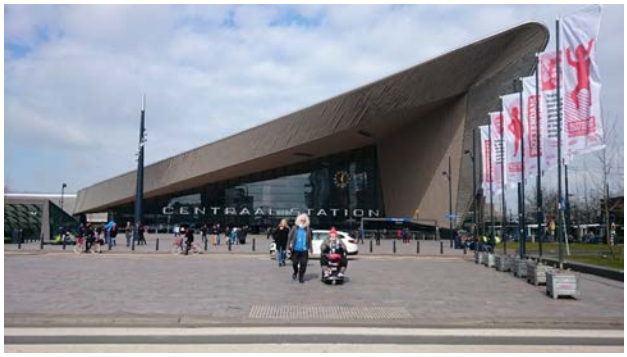


Traditionnal (up) and new (down) mobilities at Rotterdam CS © LIAT

In comparison, Nodes's analysis of the interchange zone - train, buses, metro, tram, taxi, bike:

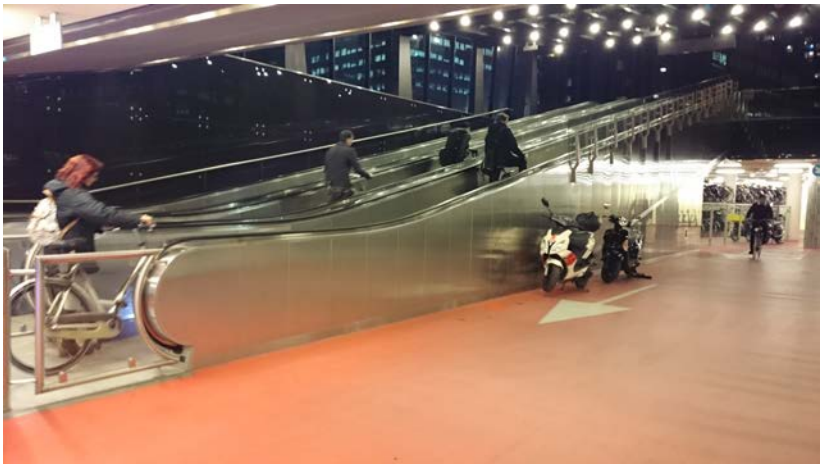


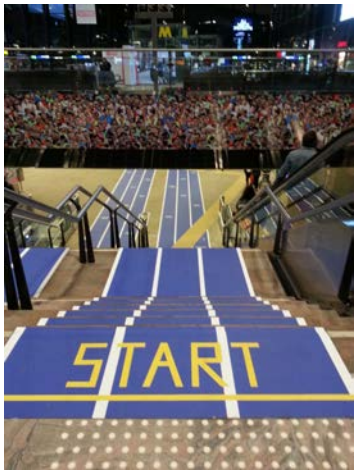
Rotterdam Central Station © Nodes Report 2013


Main entrance © Ph. LIAT


Entrance to Rotterdam Central Station, with access to the metro system and railway station directly from the forecourt / Tunnel for pedestrians and cyclists, parallel to the station. © Ph. LIAT

Besides the "grand geste" of its vast canopy, the spacious station hall and the enhancement of connections via the metro system, the next most stunning feature of the Rotterdam central station is the moving walkway for bicycles – an impressive piece of infrastructure leading directly to the station square.



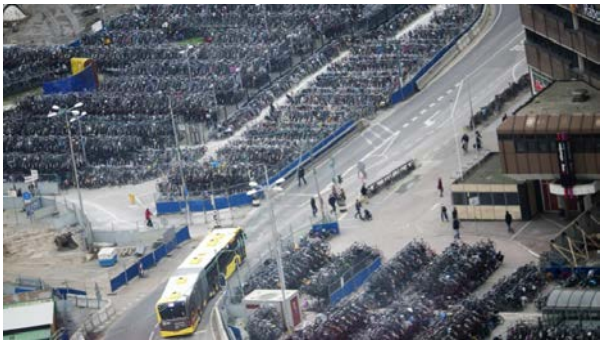


Bicycle parking facility under the station. Ramps with conveyors lead directly to the street / Design and layout of the path towards the bicycle parking facility © Ph. LIAT.

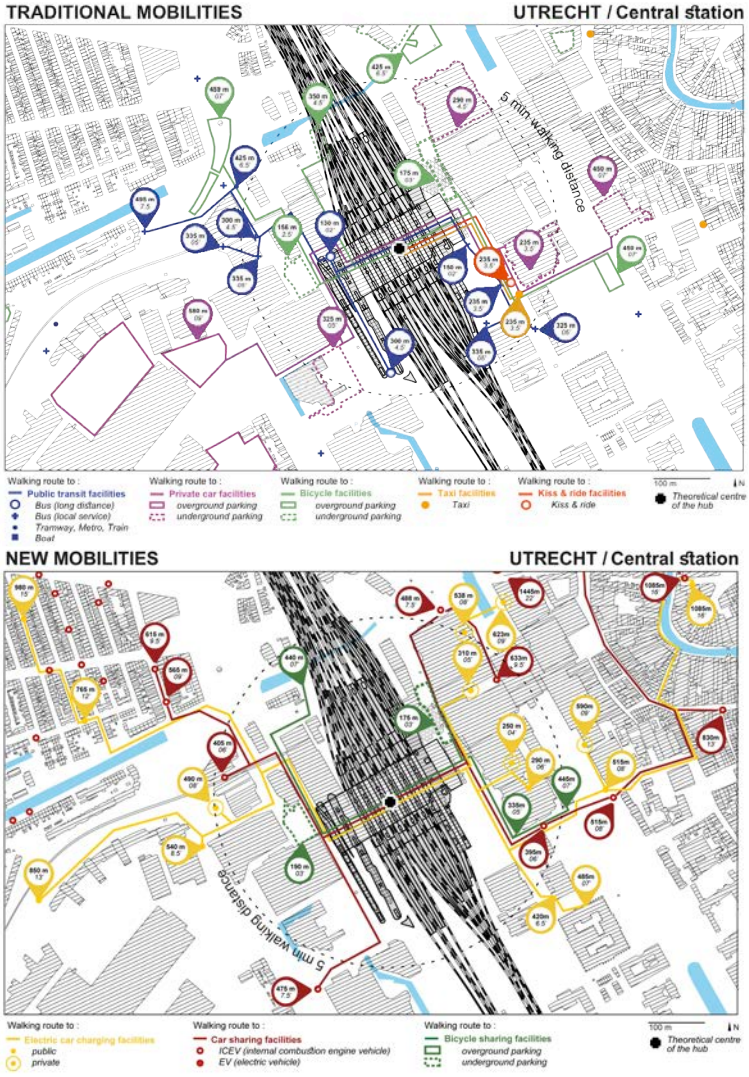
UTRECHT CENTRAL STATION PROJECT (2002-2030)

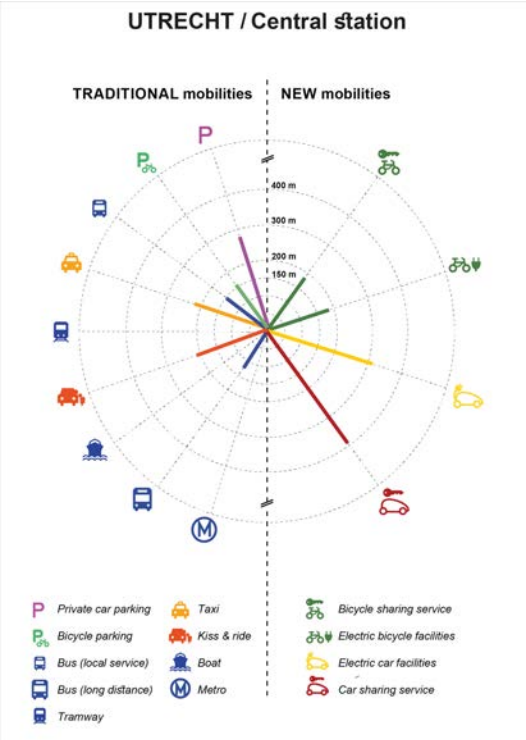
CIVITAS (2008-2012: park & ride in the suburbs) + NODES (2012-2015) + CITY HUB (2012-2015).

The aim of Utrecht central station's redevelopment project was to improve the connection between both sides of the city across the railway divide: the old town and the new urban areas that, by 2030, are expected to constitute the new city centre.



Aerial view of the project for Utrecht Central station / Current bicycle parking area near the station © Benthem Crouwel Arch.





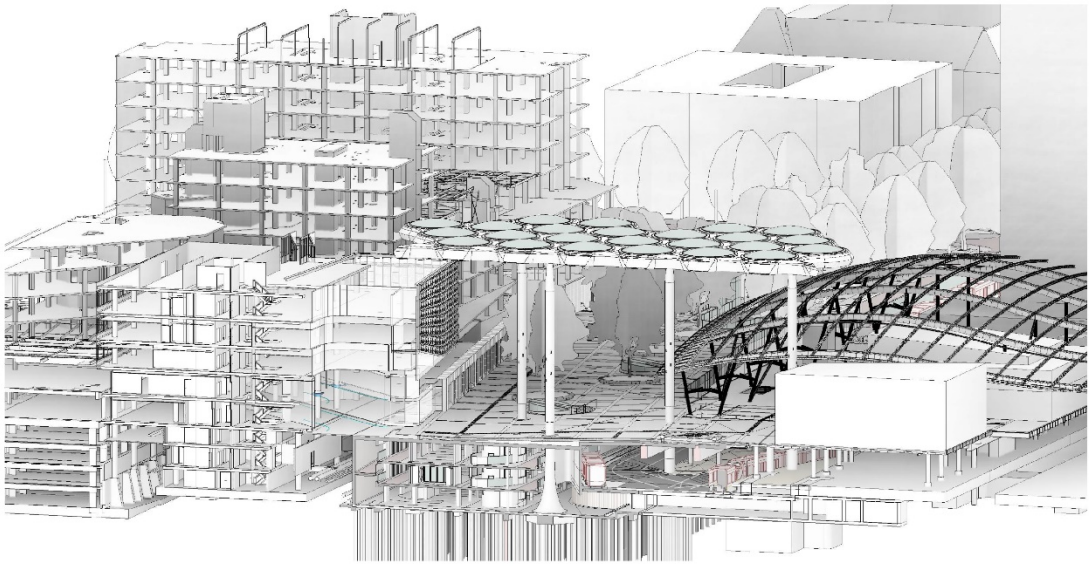
Traditionnal (up) and new (down) mobilities at Rotterdam CS © LIAT

In the university city of Utrecht, the number of cyclists is higher than elsewhere in The Netherlands. Until 2014, when the first sheltered bicycle facility was built in the central station area, bicycle parking was increasingly problematic/challenging. For students and other commuters who used the central station as a multimodal hub, finding a parking space amounted to a daily struggle. One of the semi-formal open-air parking lots still remains in use.

The first underground bicycle parking facility at Utrecht central station / Electric car charging station point © Ph. LIAT

The station area refurbishment project entailed building two bicycle parking facilities, the first of which was delivered in 2014. Today, a large number of bicycles is stored behind the station, as people wait for the new bicycle parking to be built.

An underground three-floor bicycle parking facility for 12 500 bicycles (claimed as “the largest in the world”) is expected to be the solution. According to the architects’ team, the transfer time for bicycle users was not exceed 5,5 min. Within this short time distance, users are expected to ride all the way up to their parking space (and not walk, which is usually the case in this kind of facilities), or, inversely, to reach the train platform by using three spacious staircases and multiple underground tunnels connecting the bicycle parking facility to the numerous train platforms.



Utrecht Central Station. The three-floor bicycle parking facility is located under the central public square. © Ector Hoogstad Arch.

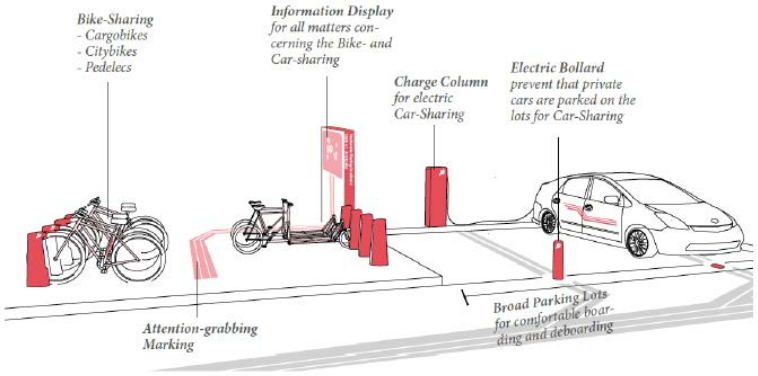
View of the cycle parking project, Utrecht Central Station © Ector Hoogstad Arch.

Construction site of the bicycle parking lot. By 2016, while still under work, the bicycle access lane was used as an inner-city bus transport route © Ph. LIAT

GERMANY

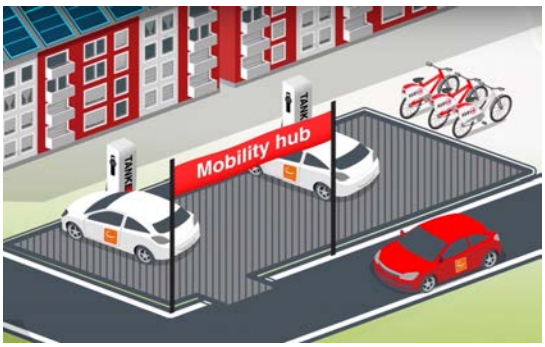
Germany is developing a broad program of mobility and intermodal services in various cities, via various bodies and institutions, with or without the help of European programs: **Bremen**'s "Mobil Punkt" network (2003-2016), Interchange project in **Osnabrück** (NODES, 2012-2015), "NETZ-E-2-R" project in the **Stuttgart** region (2012-2014), **Berlin** Sudkreuz station redevelopment (2011-2015), "E-mobility Cube" at **Wolfsburg** Mobility Centre (2013-2015), "Grow smarter" project in **Cologne** (2014-2019), Intermodal "Switch Punkt" network in **Hamburg** (2012-2014), "Your Local Market" project in **Ludwigsburg** (2013-2016), INNOZ agency for mobility and societal change, etc.
To this can be added the research carried out in the universities, for example at the TU in Berlin: Mobility and Space research unit (Centre for Technology and Society) and at the Architecture Department.

Three experimentation fields were analyzed: Berlin Südkreuz, Innoz et Bremen.



"Disposal of sharing offers at the interchange" © Joachim Kossow et al., *D4.10 Osnabruck application*, NODES consortium, 2015.

The "intermodal multibox concept", Stuttgart © : http://yoloma.iat.uni-stuttgart.de/



"Grow smarter" project in Cologne - "Switch point" station at Kellinghusenstraße ("Switch punkt" project, Hamburg).

BERLIN SÜDKREUZ RAILWAY STATION (2011-2015)

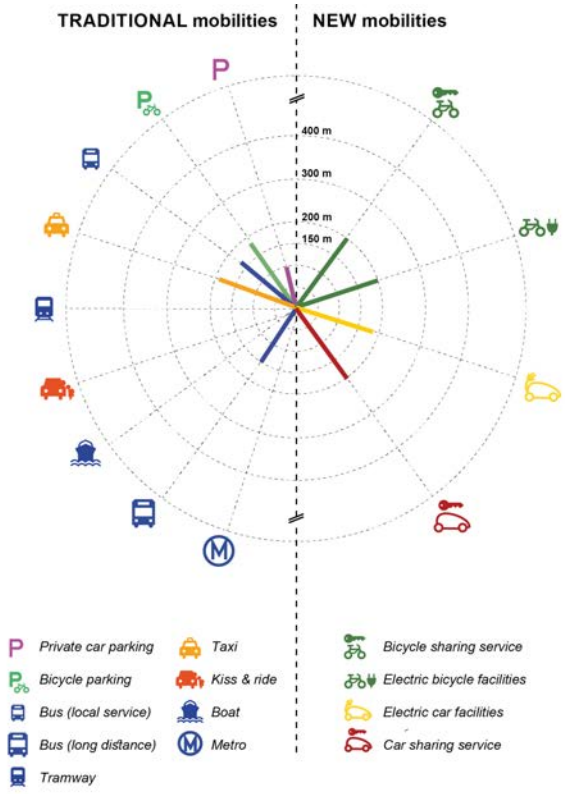
National program: Schaufenster Elektromobilitat

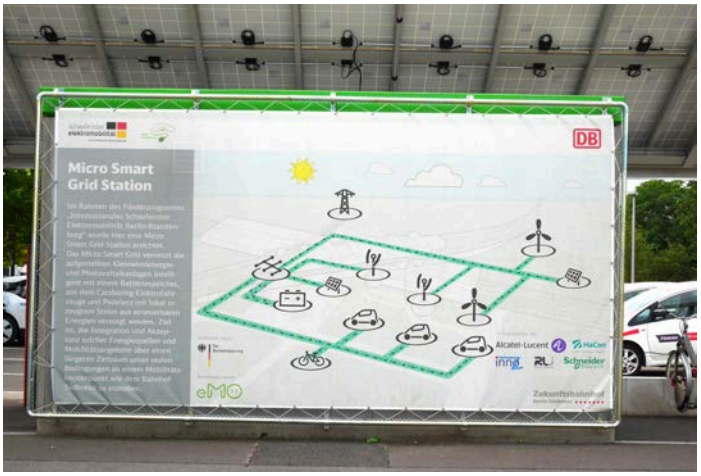
The reconstruction of the Berlin Südkreuz railway station was an opportunity to **develop an integrated system of transport modes and means of individual mobility.** The project leader was **INNOZ** – an industrial innovation company, currently funded by several local transport, energy and manufacturing firms. The main goal was **to design a model hub for the future** comprising:

- **a micro smart grid** developed to integrate several renewable energy sources (wind turbines and photovoltaic panels);
- **a new mobility offer, sustainable and autonomous from the main grid**;
- **electric and thermic car sharing services** (ICEV and EV);
- conventional and electric bicycle sharing services;
- **an electric local bus fleet**, recharged by means of an inductive plate embedded in the road surface;
- charging bays for both private and shared electric vehicles.

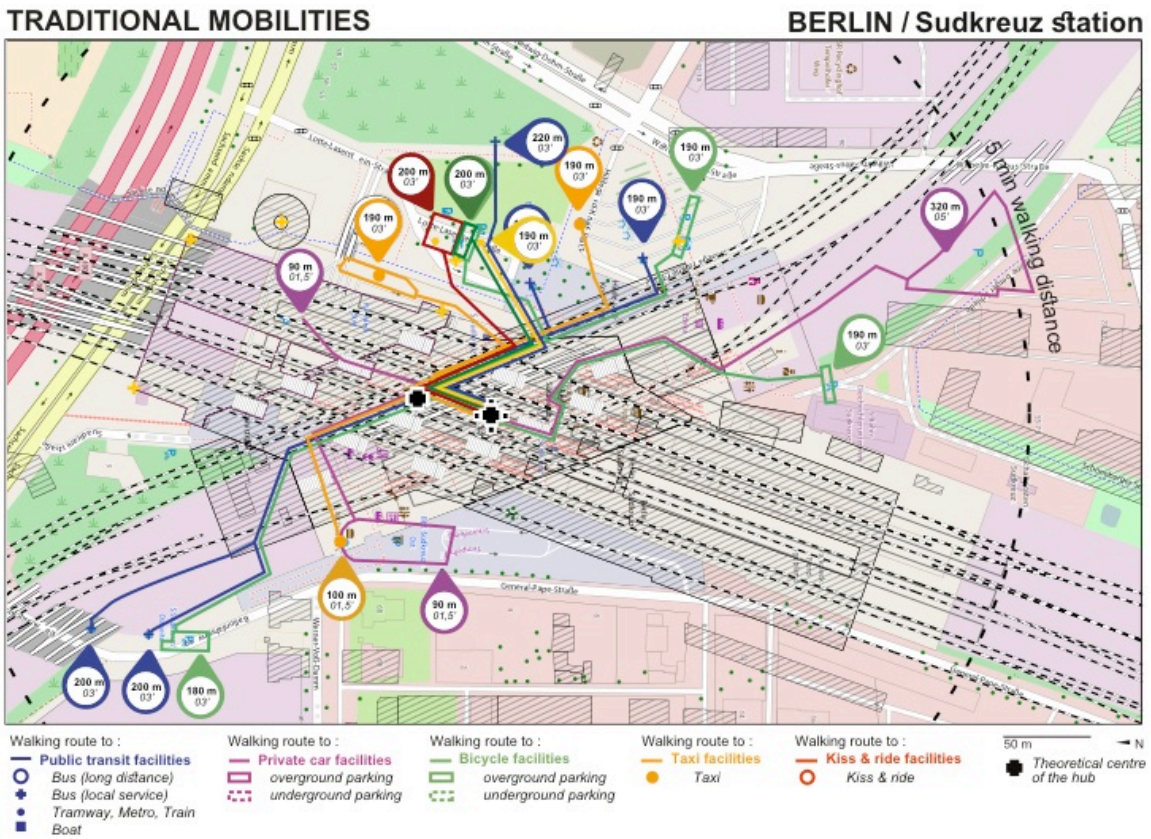
All new mobility services are displayed in front of the station, thus increasing their visibility from the traveller's point of view.

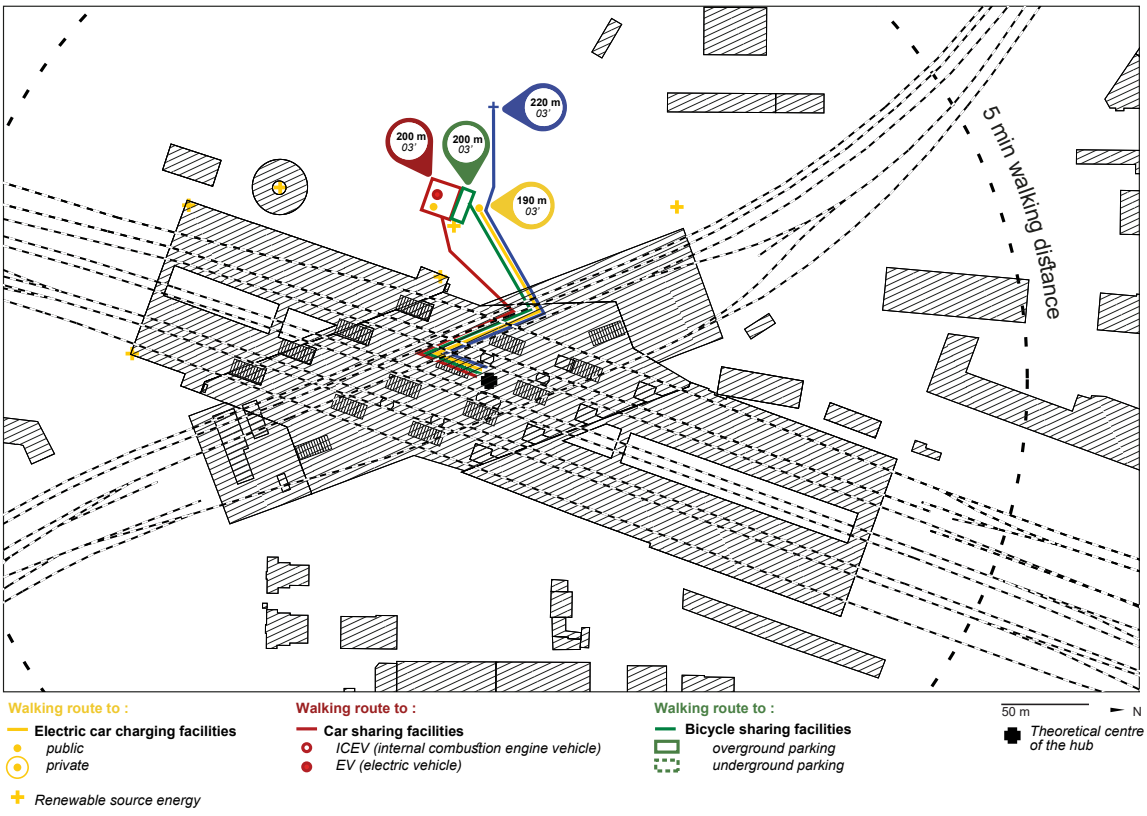
The project, however, still remains the only large-scale demonstrator of what hubs could become.





Public display explaining the Micro Smart Grid Station ©Ph. LIAT





Traditional (up) and new (down) mobilities at Berlin Südkreuz railway station © LIAT

General view of the project © http://www.bahnhof.de/asset/9141714/zipData/index.html# / Velo Easy sign system ©Photo LIAT

Velo easy bike lockers © photo LIAT

Bus inductive charging plate © photo LIAT

Parking facilities with a wind turbine © photo LIAT

Solar panels, back of the station © photo LIAT

INNOZ (Innovative Centre for Mobility and Societal Change) **/ EUREF** (European Energy Forum)

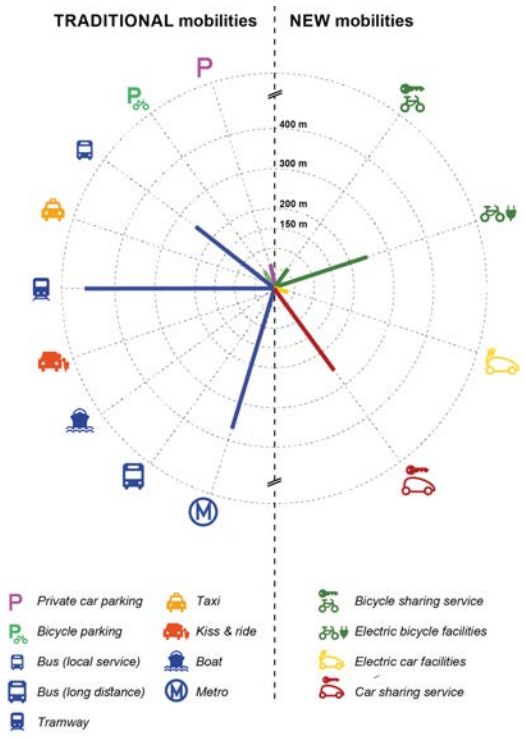
Berlin, European Energy Forum (2009-2012-2016)

As a founding generator of ideas for the EUREF project, the Innoz company used its locations as **a showcase for displaying engineering achievements**. Thus, the site exhibits a wide array of new mobility services integrated within **a renewable energy infrastructure** that ensures the autonomy of the system. A smart micro-grid prototype has been/was developed for this purpose, making use of solar, wind and geothermal energy.

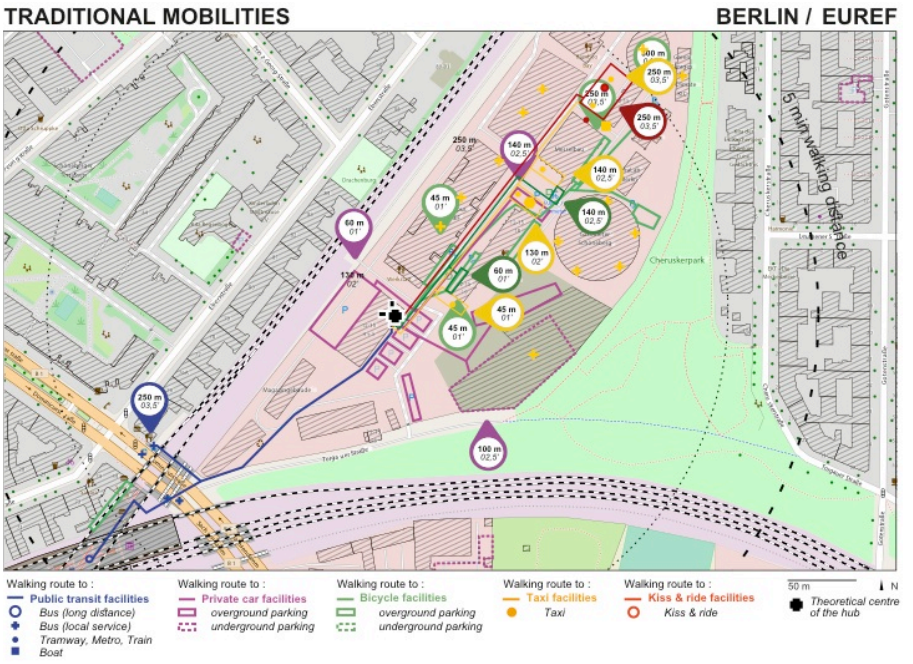
Similarly, for research and experimentation purposes, several electric charging systems were integrated in the EUREF campus. Classic cable recharging, as well as induction-based systems are available. Infrastructure for electric cars and electric bicycles is provided and can be used for private needs, as well as by shared vehicle service members.

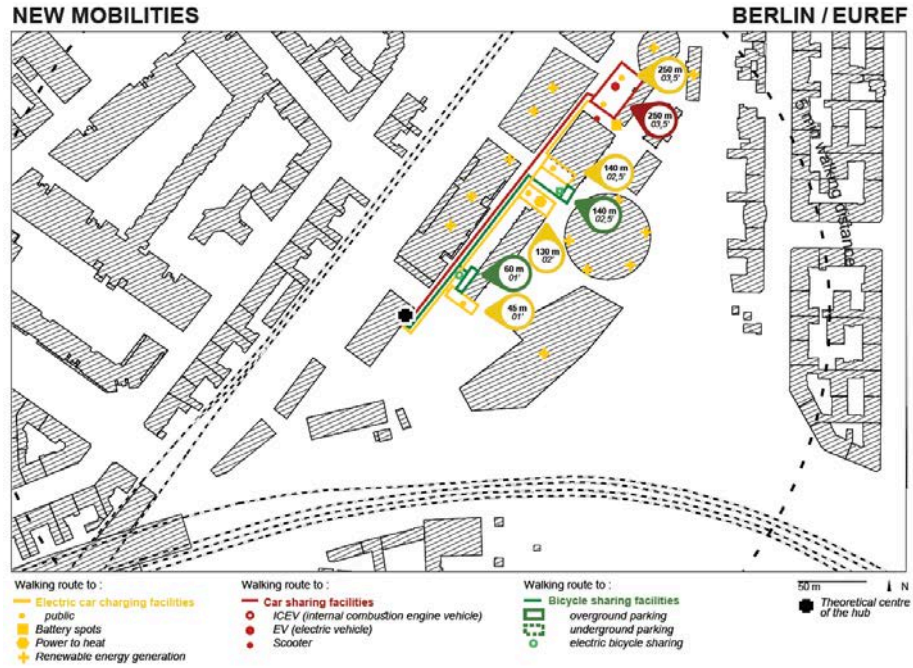
All new mobility services cohabit with the existing classic mobility offer. In addition, the recently launched **autonomous bus service** provides a connection between the EUREF campus and the Südkreuz railway station, located within a stretch of just 500 m.

The headquarters of a start-up, which operates a **free-floating electric scooter** (eMio) system, is located inside the EUREF area.



Combined street lighting and EV charging, experimented at INNOZ campus and Berlin City center © Photo LIAT





Comparison between the time distances for accessing traditional (up) and new (down) mobilities © LIAT

Different types of electric power stations - Free-floating electric scooter sharing (eMio star up on site) © Photo LIAT

FRANCE

Two French cities were selected for the study:

- **La Rochelle**, for its early pioneering experiments on what was not yet called "new mobilities", thanks to the initiatives and tenacity of the city mayor, Michel Crépeau (1971-1999). The Yelo program still pursues, to this day, similar undertakings;

- **Grenoble**, the only city in Europe chosen by the Japanese manufacturer Toyota to develop its "vision" of sustainable mobility with its program of an electric ultra-compact car sharing system for dense urban areas (**Ha:Mo : Harmonious Mobility).** The city offered, indeed, a context conducive to experimentation: an "unfavorable" geographical situation (a tightly enclosed implantation, with recurrent peaks of pollution and heat), an enticing scientific environment for the Japanese firm (CEA, CNUG, numerous university campuses), a competition with Daimler in Germany who was offering the same car-sharing service (Car2Go), and, finally, the political engagements of the Ecology Greens newly-elected mayor who had promised to support new initiatives in clean transport in his 2014 campaign.

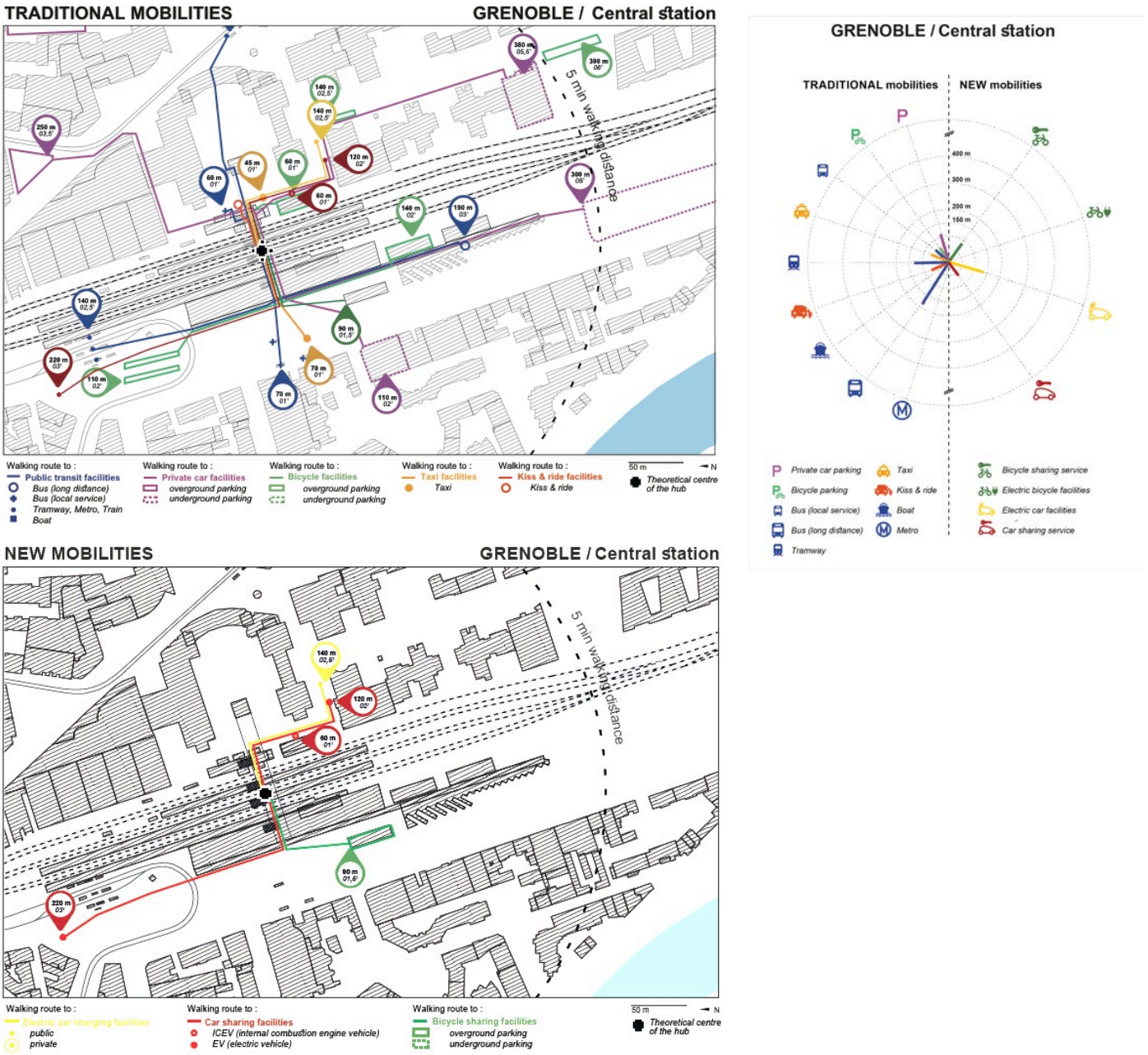
GRENOBLE STATION

The renovation of the old railway station made it possible to shorten the distance between different modes of mobility, successively located along the main façade of the passenger building. Today, the facilities provided successively comprise the following:

- The **Métrovélo** service for bicycle rental, repair and maintenance;
- **Two multi-level bicycle parking facilities** built on each side of the station (with a capacity of about 700 parking spaces);
- A **bus terminal** with a traveller waiting area;
- A car sharing service giving access to **'i-road' and 'Coms' compact vehicles for short-term lease**, provided under the 'Cité Lib by Ha:Mo' label.

Toyota delivered the 75 vehicles (including sixty units on wheels, 35 COMS and 35 i-Road units), while the City in association with five other partners, including EDF, are responsible for their installation (EDF financed the charging infrastructure which should eventually amount to 70 stations), maintenance and rental management. In Tokyo, the Japanese firm expects to replicate the French experience by 2018, while the city of Grenoble deploys a great amount energy to promote this type of shared transport and multiplies studies to understand how to increase attendance and overcome blockages: only 50% of the expected attendance was reached in 2016. In other words, improving intermodality is not yet on the agenda.

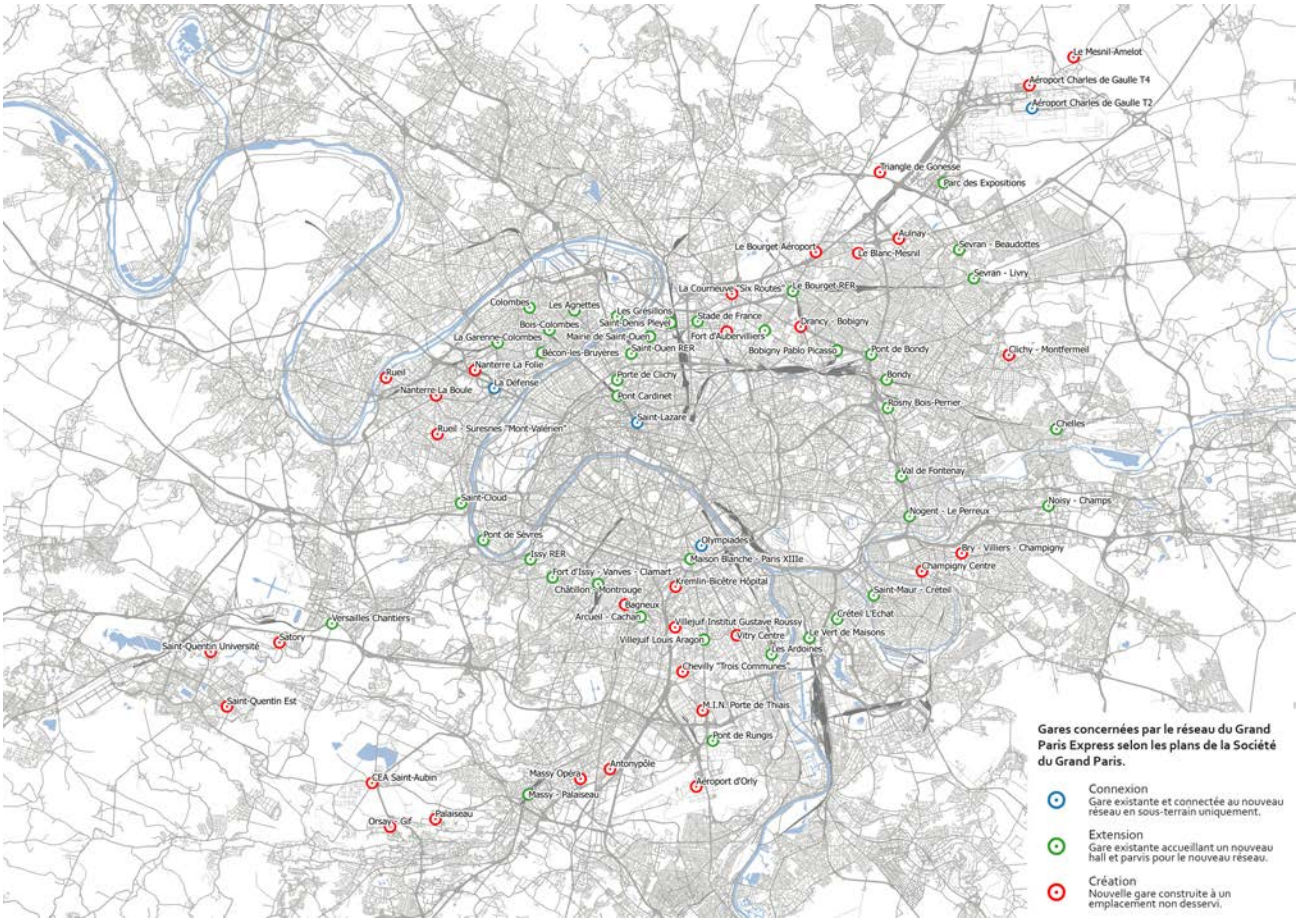
Information panel inside the railway station, without indication for Ha:Mo ride / COMS and i-Road © Ph. LIAT



Comparison of time distances to accessing traditional (up) and new (down) mobilities © LIAT

Bus station: a wall of buses. © Ph. LIAT / Back court of the station: new traveller area and bicycle silos © Photo AREP

3. GRAND PARIS EXPRESS PROJECT 2010 – 2030



73 GPE stations initially planned in 2016 for 2030: connexion (4), extension (38) and creation (31) © LIAT

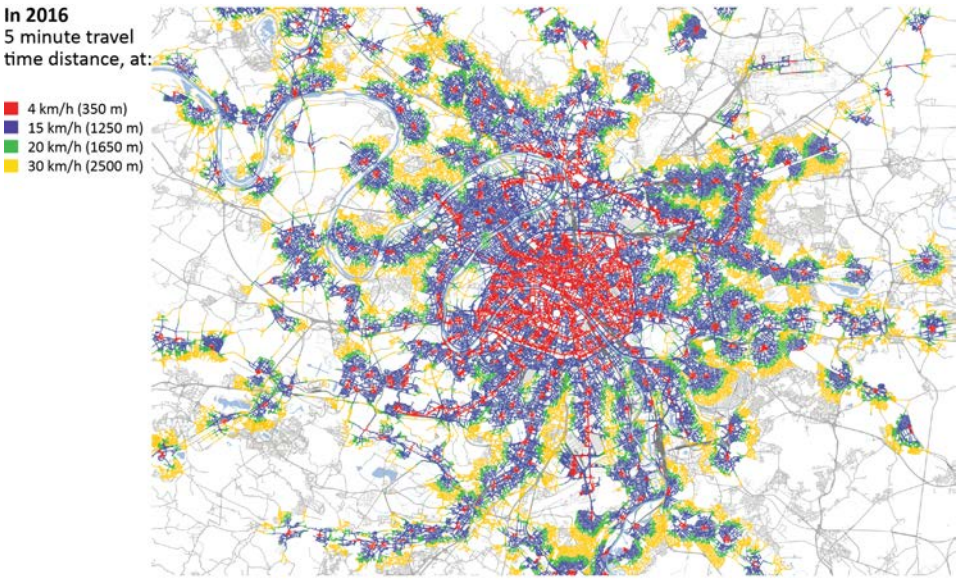
The projects of the Grand Paris Express (GPE) stations fall into three categories: fully underground connections to existing stations, extensions of existing stations with a new hall and square for the new network, and entirely new infrastructures (new stations built at a previously unserved location). In 2016, the Société du Grand Paris was still planning the construction of 73 stations (4 connections, 38 extensions, 31 new infrastructures); in March 2017, it cut back the number of "poles" to be studied to 65 stations, with three of those (Rueil, Colombes and La Garennes Colombes) to be delayed until beyond 2030. Among those projects, 22 would correspond to entirely new stations. The **Greater Paris Express** (GPE) is a network of 200 km of new metro lines (supervised by engineers) and 65 stations (handled by architects).

The GPE stations face different situations depending on the density of the urban tissue where they are located, but also, and especially, depending on the time distance separating the traveler from the station. By using chrono-geographic maps, our research once again accurately demonstrates[15] that only few of the new stations to be created, expanded or connected as part of the GPE project will offer

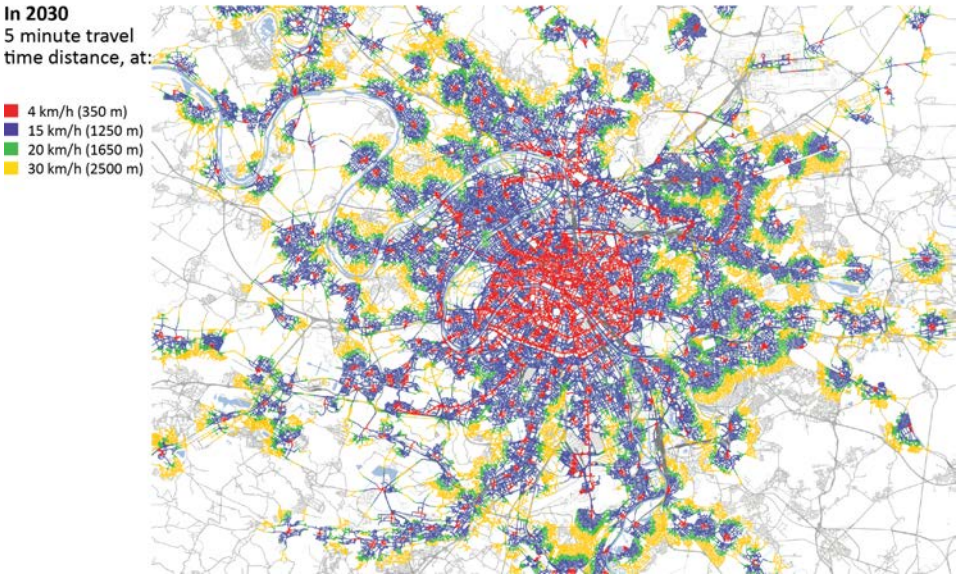
[15] A demonstration had already been made in the framework of an initial cartographic study, published in our research unit's report *Door to door. Future of the Vehicle, Future of the City*, *op. cit*. See the chapter « Proximity, an idea that is growing distant ».

increased accessibility to the users, and that the existing feeder transport will inevitably be maintained. We argue that users will continue choosing the car in situations where the walking distance exceeds 5 minutes, and even more so in environments lacking the attractiveness of commercial activities and other services.

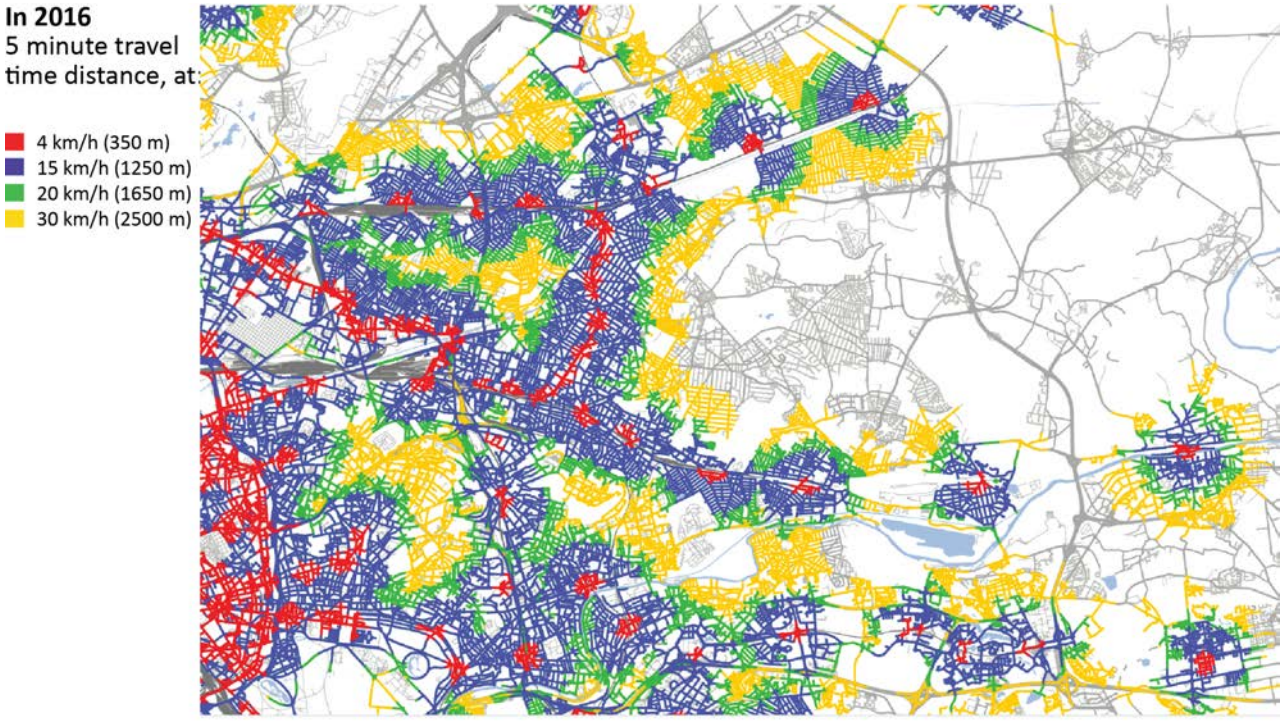
The bicycle – a key card in the SNCF and the STIF's last-mile mobility policy (the 'Veligo' concept) – will not be the answer to all situations. This non-motorized two-wheeler, operating at a speed of roughly 2 km per 10 min, will not offer an efficient solution to those who travel longer distances and/or require faster, more comfortable or otherwise more adequate options. We are convinced that new modes of transport, that could deliver shorter travel time and respond to individual mobility needs, are yet to be developed and implemented, as are the spaces of their use and their interconnexion with other means of travel.



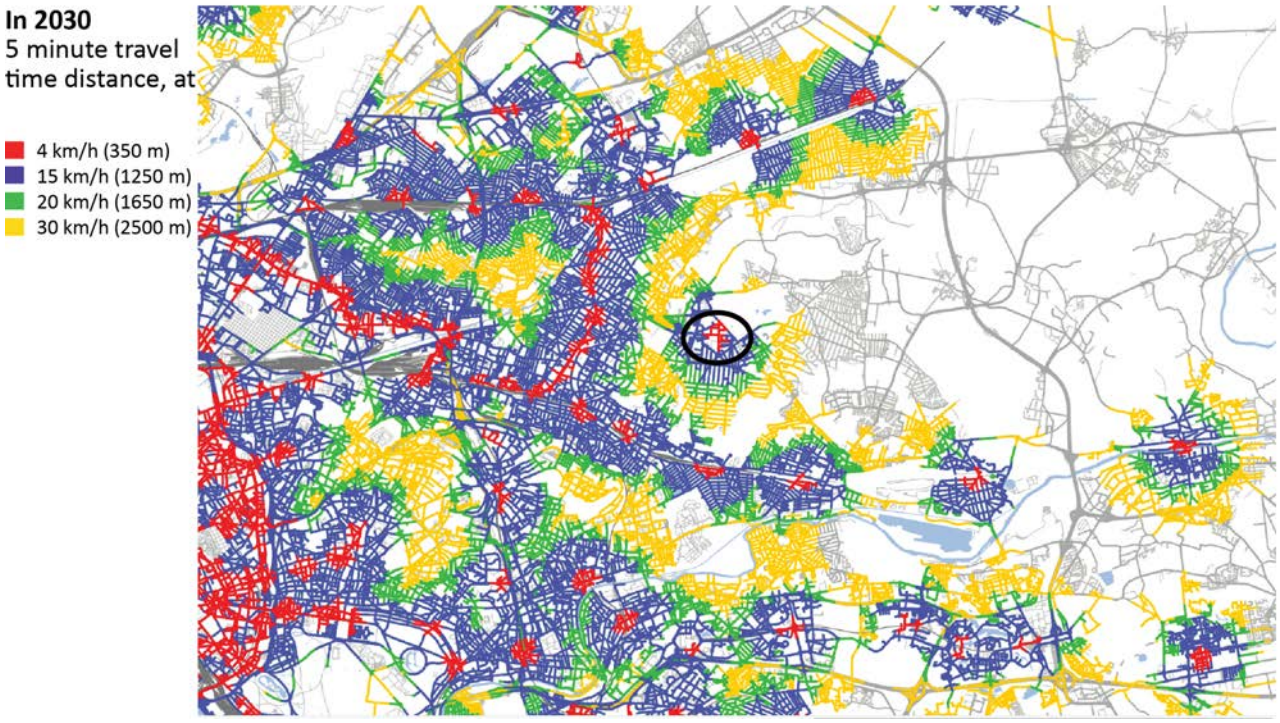
New accessibility after the creation of 31 stations



Chrono-geographic maps of the Greater Paris. © LIAT 2017. A comparison between accessibility to GPE stations in 2016 (up), and in 2030 when 31 new stations will have been created (below). Both maps show 5-minute travel time distances, covered at 4 different speeds.



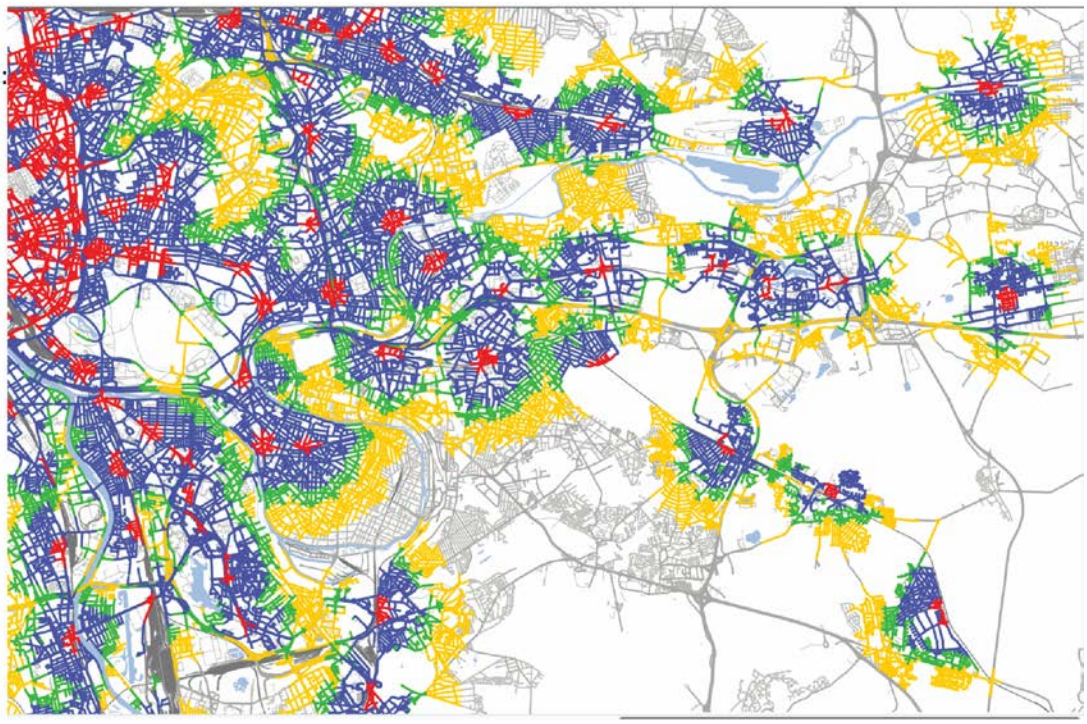
New accessibility with the creation of 1 more station : Clichy-Montfermeil



Cartography © LIAT 2017

In 2016
5 minute travel time distance, at:

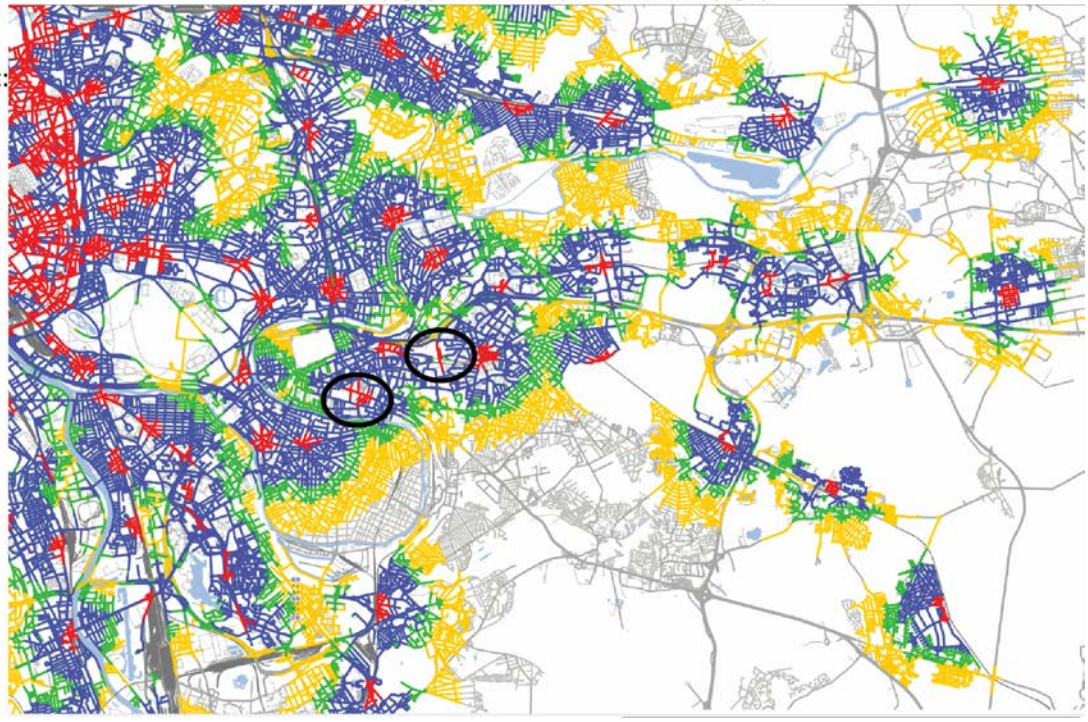
- 4 km/h (350 m)
- 15 km/h (1250 m)
- 20 km/h (1650 m)
- 30 km/h (2500 m)



New accessibility after the creation of 2 more stations :
Champigny Centre - Bry Villiers Champigny

In 2030
5 minute travel time distance, at:

- 4 km/h (350 m)
- 15 km/h (1250 m)
- 20 km/h (1650 m)
- 30 km/h (2500 m)



Cartography © LIAT 2017

Feeder transport and intermodality are therefore the major issues of the Greater Paris stations. This observation, already stated in *Door to Door*, led us to propose a typology of hubs that takes intermodality into account from the start, and not as a problem to be tackled later as will be the case in the Greater Paris projects.

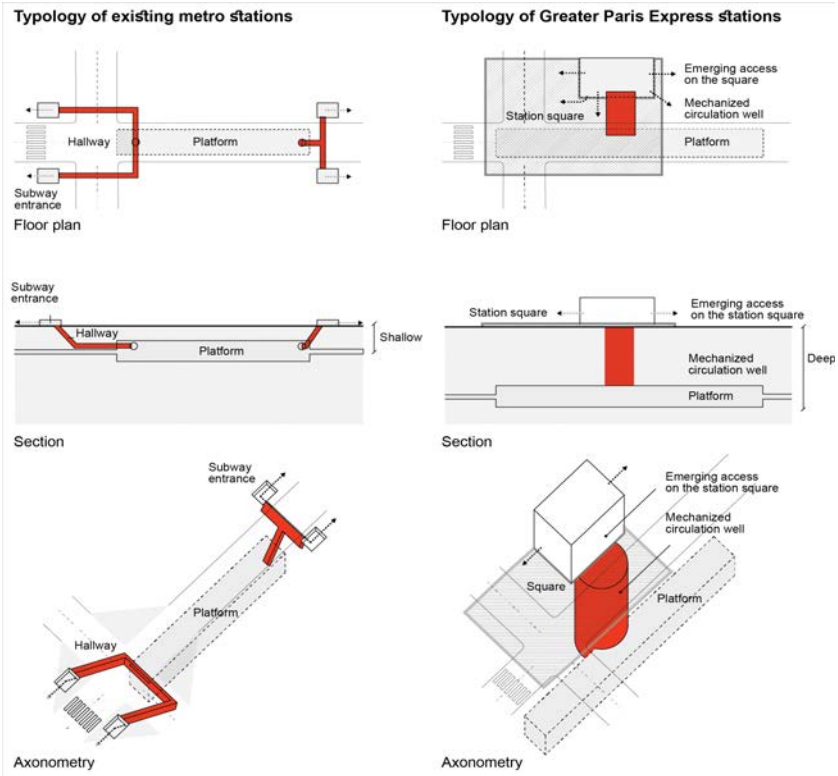
In addition, the diversity of mobility options needs to be considered as well. Indeed, the time distance will remain the defining criterion in the choice of mobility, a choice that can be expected to become increasingly opportunistic. It will thus always be very effective to use an electric scooter, a VEC, an Uber, an electric sedan or a driverless sedan to move around, even within the heart of a city center, then to drop the vehicle and, if necessary, to take a TC – if, eventually, the traffic or parking ban on individual thermal vehicles are enforced. The demand for intermodality is thus to be explored as widely as possible, especially for journeys involving multiple intermodalities.

- *Intermodality integration*

The diversity of stakeholders involved in the Great Paris Express project is considerable: the Ile-de-France Transport Union (STIF), the Greater Paris Society (SGP), the National Railway Company (SNCF), and the Paris Transport Company (RATP). Public space near railway stations is often co-managed by several players. While the Greater Paris Society is responsible for the project of the stations themselves, the design of the station squares is managed by the National Railway Company, public transport operators, as well as local public authorities and the county, who owns the highway network. Nowadays, for each "pole committee" ("comité de pole") no less than fifteen actors gather around the table.

The phenomenon of co-responsibility of different players, reflected in the conception process of new interchanges for the Greater Paris Express, represents a major challenge. The process has been divided in two phases:

First, the Greater Paris Society manages the station itself – platforms, train tracks, underground spaces and the passenger terminal –, un ensemble referred to as the "**station box**". Because the conception and construction of these "station box" projects correspond to a first phase of the Greater Paris Express program, some of them have already been built. Once completed, stations will be managed by the Paris Transport Company (RATP). The second phase of the Greater Paris Express program (since Sept. 2016) concerns the "**station square**": the outside forecourt, the public space adjacent to the station building and its immediate surroundings (residential lodgings and office blocks, as well as public amenities). This ensemble is therefore managed by other players than the Greater Paris Society.



Comparison of existing and new station typologies
(Drawing based on documentation provided by The Grater Paris Society) ©LIAT

From the outset, intermodality has not been adequately taken into account in the design of station projects for the GPE network. The problematic aspect was highlighted in a document published in 2015: Hervé De Treglode, Anne Florette, Michel Rostagnat, ***Les gares du Nouveau Grand Paris, Évaluation des dispositifs de réalisation mis en œuvre sous l'autorité de l'État,*** Rapport n° 010262-01, CGEDD. September 2015[16]. The authors of the report noted that, in fact, no intermodality requirements were put forth to the architect teams who submitted their candidacies during the first tender regarding the "station box" (2015). Demands regarding intermodality were communicated only later on, once the owners of stations had been decided, despite the fact that intermodality affects station area design in a direct way.

Moreover, the report suggested undertaking individual operational procedures for each station, and setting up an **"intermodality assistant"** for each contractor. As for the development of adjacent neighbourhoods, this study identifies two scenarios: one in which the local authorities have experience in the subject, in which case they can start a public consultation process, and another one in which the local authorities lack the required experience, in which case the Greater Paris Society takes over.

Finally, the report includes **a list of recommendations** which reveal institutional interest in new mobilities. Recommendation number 10 refers to the necessity to plan **"flexible" spaces**, so as to anticipate gradual changes in user behaviour: the report suggests "**setting up intermodal facilities**

[16] URL : http://www.ladocumentationfrancaise.fr/rapports-publics/154000791-les-gares-du-nouveau-Greater-paris-evaluation-des-dispositifs-de-realisation-mis-en?xtor=EPR-526

while preserving space flexibility in a realistic and open vision of the possible behavioural changes [17]".

The report also affirms the need "**to anticipate, as much as possible, the changes in user behaviour that will occur even though we are currently only observing the beginnings: the rebirth of active modes such as cycling, as well as the development of car-sharing, carpooling, electric cars or hydrogen cell vehicles, and the creation of a market for public transport which would benefit from parking areas in the immediate vicinity of stations**[18] ".

Further on, the authors add that "It would be interesting if the Scientific and Technical Network of the Ministry of Ecology worked on the question of **reversible car parks**, meaning parking areas which could be transformed at low cost to fit other uses than parking of private vehicles"[19].

The report also declares that "Given the difficulty to foresee, in the long term, behavioural changes in terms of "feeder" modes, and despite the political will to limit the use of private cars, as expressed in Local Transport Plans, it is recommended **to preserve other spaces for intermodal "objects" while seeking a flexibility of these "objects**[20]".

Recommendation n°10 of the CGEDD Report, sept. 2015, pp. 33-34 (*we underline*)*:*

« …le principal objet de préoccupation de la mission est le choix, semble-t-il délibéré, de la Société du Grand Paris et du STIF de **déléguer largement la réflexion, la réservation d'espace et l'investissement pour l'intermodalité**.

Les épures originelles du projet ont pu laisser craindre aux élus locaux que le Grand Paris allait les déposséder de leurs compétences d'aménageurs de leur territoire sur de vastes espaces (on parlait d'un rayon de 1,5 km) autour des gares. Mais ces craintes sont aujourd'hui oubliées : la discussion de la loi de 2010 et le remarquable travail partenarial effectué depuis lors dans le cadre des Contrats de développement territorial les rendent vaines. **En revanche, entre les choix d'aménagement effectués dans un vaste rayon autour d'une gare et ceux qui résultent des projets architecturaux qui ne traitent que la « boîte de gare », il y a pour la mission un juste milieu qui n'est pas atteint partout, loin s'en faut**.

Si les gares du Second Empire ont pu redevenir des lieux de centralité et de rayonnement urbain, c'est parce qu'elles avaient été conçues à l'origine, aux portes des villes, au milieu de généreux espaces fonciers. Il n'est évidemment plus question, s'agissant de gares qui pour la plupart s'installeront au cœur de quartiers fortement urbanisés, de prétendre à de telles exigences. Mais il est important que la gare soit conçue concomitamment à ses espaces de desserte.

Et il convient en la matière d'anticiper autant que possible les comportements de mobilité à venir, dont on n'observe actuellement que les prémices : renaissance des modes actifs comme le vélo, autopartage, covoiturage, voitures électriques ou à pile à combustible, création d'un marché pour le transport collectif routier interurbain qui nécessitera des espaces de stationnement dans les gares les plus accessibles de l'agglomération, etc.

C'est pourquoi **la mission recommande fortement que soit mise à l'étude de manière plus volontaire la programmation des opérations nécessaires à la bonne intermodalité dans toutes les gares du réseau nouveau, afin que l'aménagement des quartiers riverains ne vienne prématurément contrarier leur mise en œuvre.**

Il serait intéressant que le réseau scientifique et technique du ministère de l'écologie, notamment le CEREMA, travaille la question des parkings réversibles, susceptibles d'une transformation peu onéreuse pour d'autres usages que le parking.

10. Recommandation : **Engager la programmation des équipements liés à l'intermodalité en préservant la flexibilité des espaces dans une vision réaliste et ouverte des évolutions possibles des comportements des voyageurs. »**

[17] De TREGLODE, Hervé, FLORETTE, Anne, ROSTAGNAT, Michel, *Les gares du Nouveau Greater Paris, Évaluation des dispositifs de réalisation mis en œuvre sous l'autorité de l'Éta*t, Rapport n° 010262-01, CGEDD, p.34.

[18] Ibid., p.34.

[19] On these assumptions see D. Rouillard et A. Guiheux, *Door-to-door, Future of the vehicle, future of the city*, *op.cit*., chap. « The parking facility as future », p. 204- 225.

[20] Ibid., p.29.

To remediate for the omission of the intermodal question, in February 2016, the Greater Paris Society created the "**Public spaces and intermodality unit**" with the mission to solve the issue of intermodality.

• *« The STIF must update its vision of intermodality »*[21] .

In June 2017, the STIF published *Les nouvelles gares d'Île de France, Multimodalités et services de demain*, which this time integrates the issue of intermodality. The documents propose to move « From transport to mobility in 10 perspective points for the design of tomorrow »:

1. Towards more and more new private and/or public mobility services.
2. Density: a key factor for the success of emerging mobilities
3. Stations that adjust to density. The document identifies 3 types of station that, depending on the population density, would not offer the same mobility options: - a varied and ubiquitous offer in the public space for the hyperdense city where space is limited or nil; - the widest mobility offer in the suburbs where space is available; - low supply outside of the dense area.
4. Usage conflicts not to be overlooked.
5. Paradoxically, basic comfort as a short-term development axis.
6. The smartphone as mobility assistant.
7. Electric, automated and self-driving vehicles that will have an impact on the organisation of the stations.
8. To open the station onto the city, to open the city onto the stations.
9. To design flexible spaces.
10. To stay tuned [22].

The document illustrates these points through four examples of stations in 2025:

1. T

he station at the heart of the city. To adapt the city to new mobilities:
Automated buses, connected scooter stations, electrically-assisted bicycles, secure bicycle parkings (Véligo).

2. In the inner suburbs, the station meets the demand for commercial services and mobility: Automated vehicles (shuttles or robot-taxis) and shared vehicles for the last kilometer, sharing of individual vehicles (with meeting areas), shops and ephemeral spaces.
3. In the outer suburbs train station, a showcase of the multimodal offer:

A more welcoming traveler space (increased and optimized pickup and drop-off areas, very comfortable "indoor" stations), a remote technical area, intensify multimodality and optimize management thanks to digital technology.

4. In the "end of line" stations, flexible spaces: modular and flexible Park and Drive facilities, to welcome and encourage other uses (fresh produce retail outlets, booktracks), to guarantee the comfort of travelers (more secure and comfortable waiting areas).

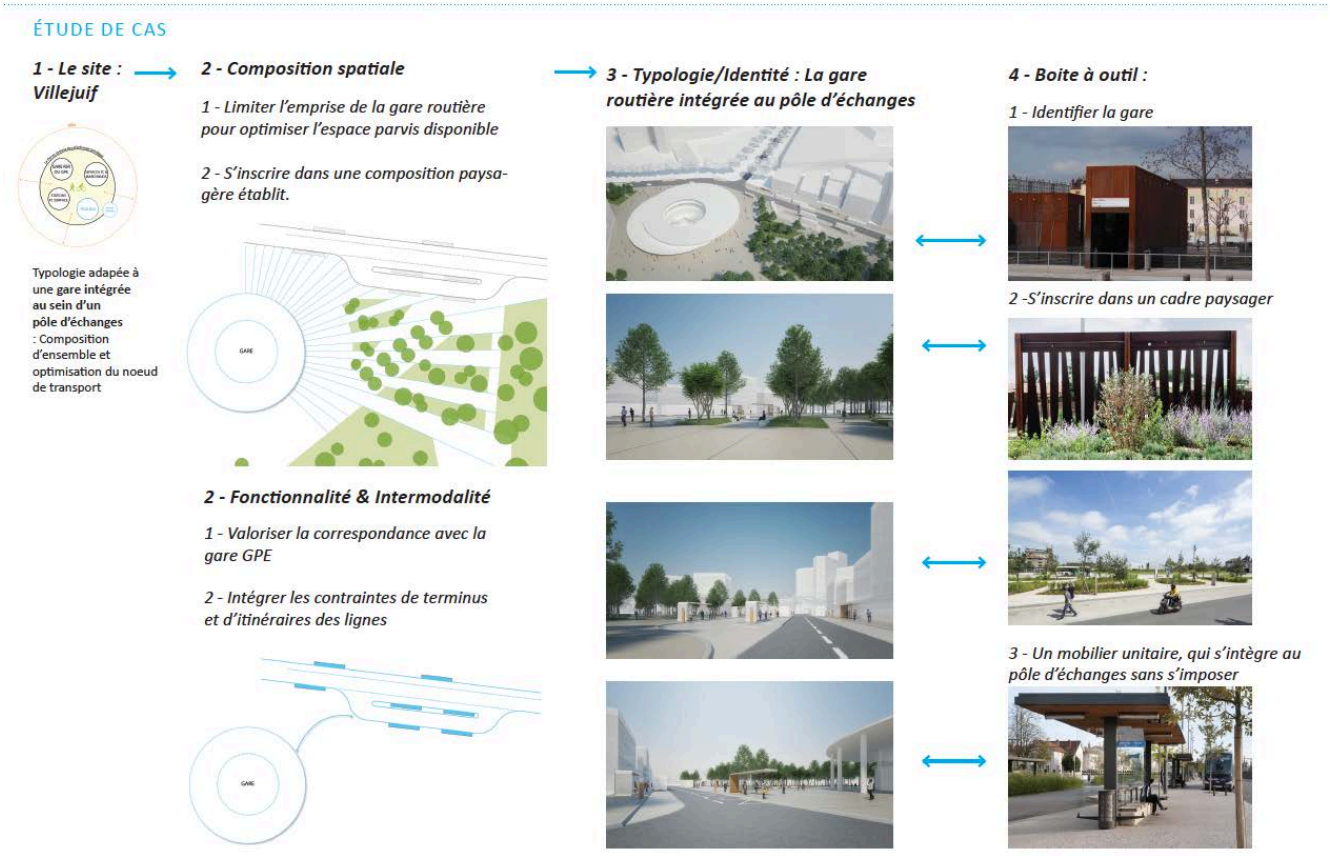
The STIF's objectives here remain fairly moderate and barely interfere with existing stations where construction is in progress. Furthermore, the hierarchy of stations seems very dependent on the

[21] *Les nouvelles gares d'Île de France, Multimodalités et services de demain, juin 2017*, p.1. On this occasion, the STIF renamed itself "Île-de-France Mobilités".
[22] Ibid, p. 9 ff.

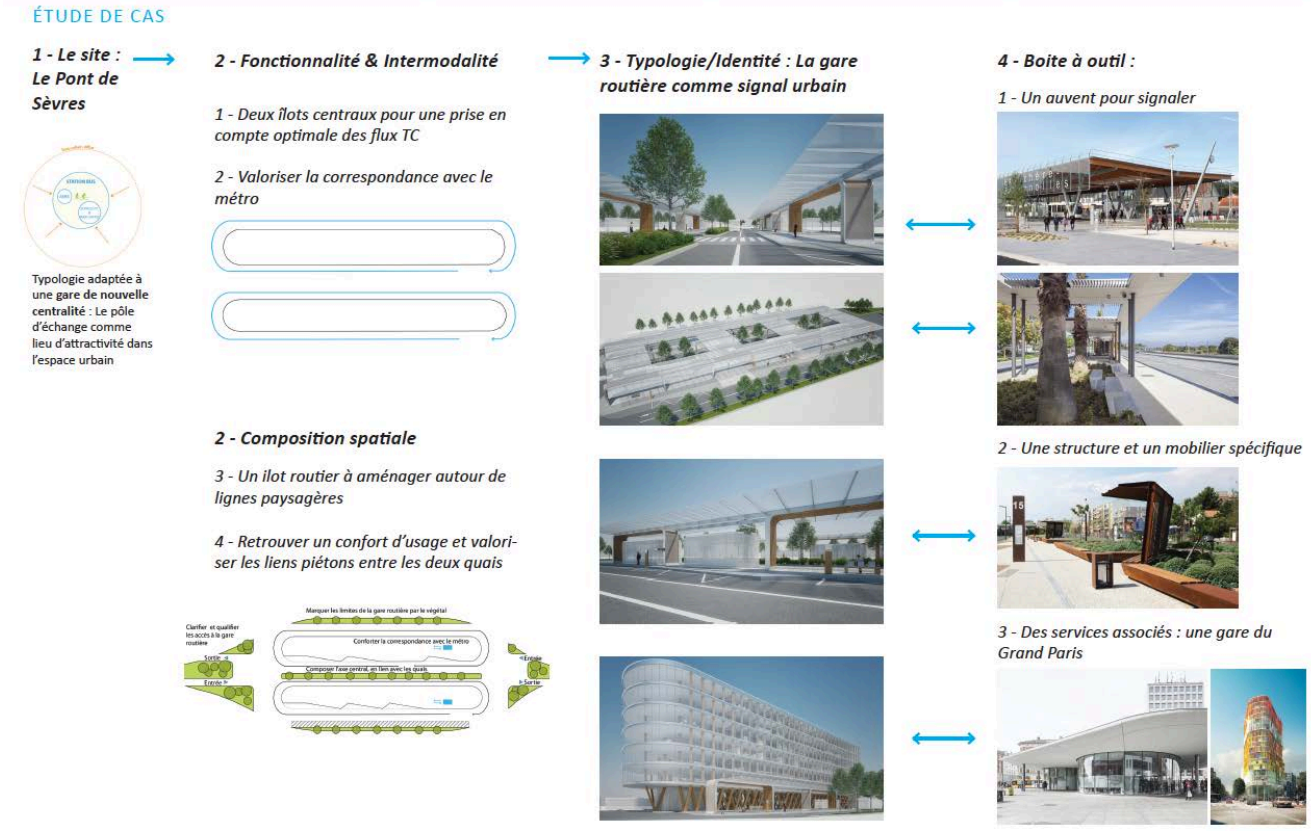
available surfaces, despite the undeniable need for parking facilities, visible around stations, available for bicycles, scooters and four wheels.

What the STIF proposes does not emerge as a true development or redevelopment project of services and urban activities. The station continues to be considered as an isolated entity, centered on transport activities, and therefore not reflecting the major reversal initiated from the start by the Japanese station. The urban programming dimension and the real estate development are in fact the missing links among the partners.

Model of Intermodality concept according to STIF / Île-de-France Mobilités. Villejuif and Le Pont de Sevres Bus Terminal in relation to a GPE Station (September 2016). The main concern in terms of intermodality remains the link among heavy transport means.



Villejuif Bus Terminal projects © STIF



The Pont de Sevres (bottom) Bus Terminal projects © STIF

CONCLUSION OF CASE STUDIES

As stated in our two-fold research goal, we sought to assess the stage of hub development and optimisation, essentially in a context of profusion and hybridity of travel modes. Our research has shown that a significant number of studies and achievements have already been carried out on the subject of exchange hub performance and functioning. However, scholars as well as project managers rarely take into account the possible improvements and transformations set in motion by the introduction of new vehicles and new mobilities. As we have already underlined, there is an enduring focus on existing systems and infrastructure and lack of prospective research with regards to spatial analysis.

A paradox: the profusion of intermodal use and the simultaneous lack of knowledge about it.

Another finding of our research concerns the amount of knowledge that transport authorities, service companies and station operators effectively have about the user of shared mobility services and new kinds of vehicles. In fact, as far as we can tell, none of the urban transport operators met by us is currently collecting information on the patterns of intermodal use. This is a paradox, given the fact that providers of shared mobility services do collect data on all their clients, mainly thanks to the digitalisation of their infrastructure. The lack of regulation in the field of data use is often mentioned as a core problem issue. Let us recall that European research has led to significant gains in terms of knowledge of the reasons for and against intermodal choices. Our belief, then, is that research findings are insufficiently communicated and therefore remain little exploited outside the framework of each research contract.

The quest for business models overshadows the need to devote more efforts into the design process

In many cities and countries, the difficulty to finance new mobilities is seen as the main issue. Thus, more funding and energy are committed to finding the adequate business model than to actually implementing the new system. Such initiatives as the call for proposals launched by De Verkeersonderneming in Rotterdam attest to this phenomenon. Similarly, the 'Ubi Gothenburg' experimental platform for intermodal mobility demonstrated the fixation with finding 'the best model', while practically no attention was devoted to designing the urban space where the new services were to be made available.

The risk of such strong focus on business models is that cities might never actually solve the modal shift problem. Comfort of intermodality, time distance, offer and visibility of mobility services and modes, the new role played by parking facilities, the new approach of the public space and so on, must be considered fundamental issues if stakeholders are to succeed in their mission to free cities from congestion, polluted air and noise by means of intermodality – and, in so doing, to transform urban development as a whole.

II/ NEW HUBS FOR NEW MOBILITIES

Our research approach and methodology are founded on the tracking of outstanding examples that may stimulate the possible evolutions of hubs in the immediate future, as well as of weak signs. Japanese stations, recognised as the world's best performing have thus weighed significantly in the conception of our proposals, the first drafts of which are presented here.

1. A large common space

We have called our first hypothesis "the large common space". The blurring of limits between buildings and vehicles is typical of the new use of public space. In "shared spaces" (zone 20) for example, where pedestrians hold priority, "the large common space" is the concept that best describes the new public space. For Constant, from whom we borrow the expression, the "large common space" responds to the need to fight against a fact of contemporary time: "We cannot allow traffic to destroy the social space of cities"[23] .

Our research sought to highlight the changes introduced by the ECV in the very heart of exchange poles. Its environmental qualities make it possible for the ECV to enjoy great proximity with pedestrians.

One single building

The lack of noise and air pollution associated with the latest environmentally-friendly electric vehicles favours their growing presence at multimodal hubs and makes it possible to follow principles developed in the sheltered, multi-storey modern stations of the 1960s.

The station thus becomes a sheltered and protected building, accommodating all programmes and intermodalities under the same roof. The silent and clean nature of environmentally-friendly vehicles favours this integration of modes, services and spaces at the architectural scale. While buses and taxis were the first to be present in such buildings, personal vehicles have remained side-lined, either parked underground or stored in outdoor parking lots, increasingly less tolerated at drop off points. However, as we have already shown in the *Door-to-door* research, the separation of mobility modes is no longer relevant, especially since the arrival of the ECV. Dutch examples show that it is possible to cycle inside hubs, and that soft mobilities of that sort have found their legitimate place inside the facility. This evolution –bringing vehicles closer to the users and allowing them to circulate inside buildings – makes it possible to reduce the travel time distance inherent to intermodal mobility.

We formulated a hypothesis in favour of the compression of various zones (service area, arrival/departure and interchange zones, facilities, platform area) facilitated by the advent of ECVs. Generally, ensuring the shortest distance between starting and boarding points should be the target. However, for various reasons this is not always the case.

[23] *Internationale Situationniste*, June 1960. For more on this subject, see Alain Guiheux, *L'architecture transforme. Le grand espace commun*, Genève, MetisPresses, 2017.

The Japanese contribution achieved the osmotic blending of the station with urban life, manifested by a hybridization of the commercial spaces and the station, which interfere with each other and spread, no longer bound by any dividing lines.

Kishiwada illustrates the urban spaces to come where environmentally friendly and self-driving vehicles are reintegrated in the city. The picture (left) shows how the commercial covered street, starting at the station, spreads within the urban tissue (Photo Wikipedia common).

Activities and intermodality

We have considered as equivalent all programs present within the station.

Whereas in preceding decades stations were conceived as a set of separate programs, it has now become relevant to consider integrating all programs within a vast common space. To put it differently, intermodal programs will be combined and intertwined, or integrated as part of a larger walking sequence, together with other programs, commercial activities and various related services. Just as intermodal links must be the shortest possible, we wish to reiterate, here, that the more the service and retail activities are gathered near railway platforms and hub exit areas, the more they are "ergonomic" for users.

Commercial and mobility services have historically developed overlapping relationships by means of spatial links at various levels of the hub. In Japanese stations, this is a former pattern, with aerial, underground or ground-level shopping malls having been built at connection areas. In the *Door-to-door* research, we also demonstrated the importance of providing virtual shops on railway and metro platforms.

Thus, what makes sense in the Japanese station with regard to the intermodal issue, is not, in itself, the presence of shops and other services – in our days, every station aims to become an internal shopping center, a goal long time accomplished by certain world stations, from the Grand Central Terminal in New York to the ShopVille-Zurich station in the 1990s. The Japanese defining trait is, rather, the fact that the (necessary) interconnection between the various private train lines, and the long walking distances that result from it, are what prompted the development of those shops and services. The link between interconnection and business activities has since then become structuring[24]. Intermodality adds to interconnection and strengthens this association.

[24]Comparatively relevant, in this sense, is the former role of the railway in urban development, reinforced after the destruction of the Second World War: the stations were rebuilt instead of the downtowns, with their transfer


Nagoya Central Station, inside the linear commercial streets linked the different lines of transport / View from the frontcourt, with the new fourth tower on the right © Photo LIAT

Multiprogramming as lifestyle.

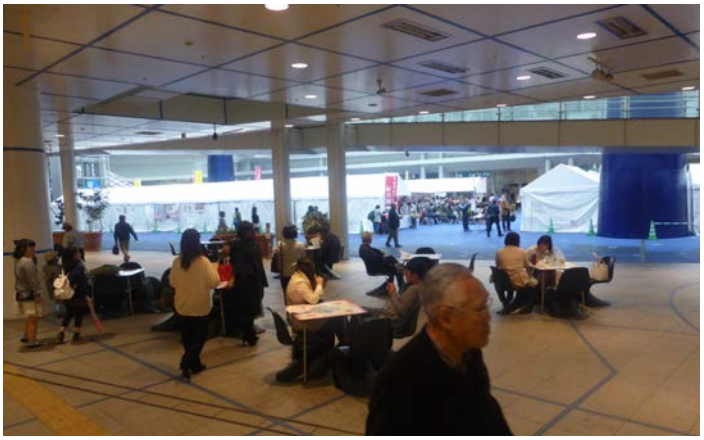
New mobilities are making their way into the very core of hubs whose function has been deeply enriched. The transfer experience during trips has been considerably modified. Waiting for the train, commuting, travelling, are no longer primary activities and now take place simultaneously along with reading, working, eating, doing online purchases via Smartphones and other activities. The change in transportation modes during trips has become an opportunity to do other things. Multiprogramming has turned into a lifestyle.

Putting to use the traditional waiting time is, in any case, a key factor in the comfort value of the transfer. From the bus stop to the international hub, each station has become an added-value location for other compatible activities of a commercial, cultural or public service kind.

A similar logic underlies the development of leisure activities (public pianos, fitness and spinning parlors, etc.) and the spread of bicycle repair stores and bicycle racks. Smart-building is above all a succession of programs and its consequences are immediate. These program sequences are installed at the very heart of inter-multimodality stations, first and foremost vehicle-sharing recognized as a full-fledged means of public transportation.

The large common space will also be flexible, taking inspiration from airport terminals which have since strengthened this association. The interrelation between activities and intermodality will thus be more and more the occasion to develop new spaces, new typologies and new uses.

halls lined with shops and services playing the role of urban streets. See Corinne Tiry-Ono, *Architecture of displacements. Japan's railway stations*, Gollion, InFolio, 2018.



In-outdoor space: The Nagoya Bus Terminal © photo Liat / Multiprogram: the Kashiwanoha-campus station (Tokyo) © Photo LIAT

Pedestrians and the architecture of time

Within the vast common space, pedestrian users are the measure of all movements: they have become part of the machinery of the hub, and the speed at which they move, as well as their comfort experience, will dictate all other activities.

The internal atmosphere of the large common space ensures the functioning of the station, which is organised, above all, from the ergonomic perspective of movement and by an “architecture of time” that makes comfort its first priority.

The elevator and the escalator were offsprings of an architecture of time; automatic parking for bicycles and cars are more recent expressions of the same breed. It takes 5 seconds to drop one’s bike in an automatic parking, 20 seconds in the case of a car.

Tokyo, Shinagawa station: Giken underground Eco-Cycle parking system (left) and Giken Eco-Park (Anti-seismic Underground Car Park) (right) © Photo LIAT

The intermodality journey

The distances to be covered are as relevant as the availability of modes of transport, services and activities easily visible from inside the station space. The overall ergonomics of exchange poles proposes modes and activities which are the closest possible to each other in the context of the emergence of new carbon-free connected vehicles.

Gathering all modes as close as possible to the railway, **organising a succession of modes along the chain, is part of an overall time management strategy.** Just as stores and services are more "efficient" when they are close to one another, so the practice of intermodality tends to regroup the offers of vectors of mobility. The theoretical spatial arrangement of 30 mobility vectors (see page 8) becomes a complex challenge.

Shinagawa Station (Tokyo): from the station platform, visibility and continuity of the pedestrian route with immediate access to the bus, shared electric bikes and the underground parking for automatic bicycles. Photo © LIAT

From the platform to the hall

Finally, let's point out that the large common space is also **a place for genetic transformations**. The experience of boarding or descending from trains and buses no longer means a transition from cold to warm environments or the other way around. The space of the interchange has become a sheltering continuum, the expression of a new level of comfort brought to the intermodality experience [25].

Nagoya station and bus terminal Nagoya © Photo LIAT

[25] An example of this principle was installed in La Défense, many years ago, for the bus terminal Jules Vernes.

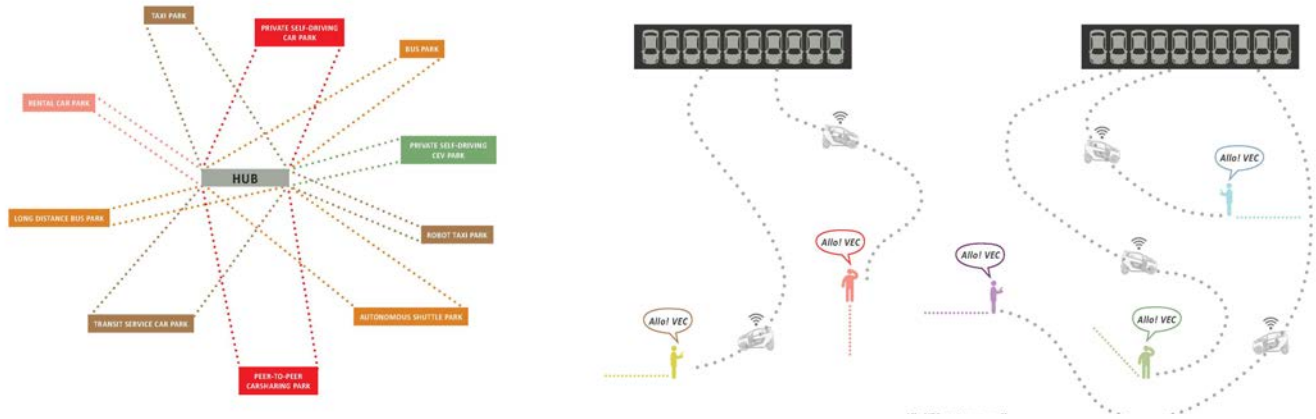
2. Revolution: the vehicle comes to you

Another hypothesis consists of reversing how we understand and interpret vectors of movement.

Currently, carbon vehicles are parked in separate spaces, which results in considerable travel and often additional transfers for passengers. With the advent of environmentally friendly self-driving vehicles, it will be possible to reverse this habit by bringing vehicles closer to the platforms: then, it will no longer be the passenger who must walk, take the elevator, the ramp, the stairs or the corridors, but the vehicle that will do it for him; while we still consider that it is us who must move towards vectors of movement, a more efficient configuration is to expect them to come to us on their own.

This relevant mindset dictates **a separation between the parking function and the management of the pick-up and drop-off areas.** Comfort and space economy are thus profoundly modified. .

The dissociation between stop and parking facilities is also efficient for taxis, EVCs and other mini-buses. These vehicles can be remotely parked and arrive at the station on demand. The location of the parking lots housing the various vehicles is not decisive in the efficiency of intermodality. It is possible to think of multiple parking facilities sites, located at "5 minutes" or at "the last mile" of the station itself.



Remote parking facilities away form the station / « Hello, VEC, come and get me ! ». Inversion of pedestrian/vehicle movements ©IAT

The arrival of autonomous vehicles will even further accelerate this transformation, and increase the efficiency of the Stop/ Parking dissociation: “Hello, VEC, come and get me, I will be waiting at point X…”.

The self-driving vehicle revolution has arrived**: it is no longer the passenger who moves to look for his vehicle or his taxi, but the vehicle that goes meet its passenger, wherever he is.**

APPENDIX

LIST OF REFERENCE INSTITUTIONS AND INDIVIDUALS

		Institution / Company	Name and affiliation
EUROPE		**Luxmobility Consulting company French** **Ministry of Education, Higher Education and Research**, General Directorate for Research and Innovation **French Ministry of Environment, Energy and the Sea**, General Delegation for Sustainable Development, Directorate of Research and Innovation, Innovation unit+	Mr. Patrick van Egmond, Managing director **M. Philippe Toussaint,** Principal Advisor for Sustainable Mobility & Transport, General Directorate for Research and Innovation **M. Michel-Louis Pasquier,** Deputy to the Head of Unit in charge of European and international Cooperation
NETHERLANDS	AMSTERDAM	**Benthem Crouwel Architects** (BCA) **International industrial fair and symposium "Intertraffic"**	**Mr. Jan Benthem:** co-founder of architectural practice **BCA**. Representatives of the Dutch national infrastructural innovation programme 'Beter Benutten' (improved accessibility)
	ROTTERDAM	**De Verkeersonderneming** (DV) **Nederlandse Spoorwegen** (Dutch national railway company).	**Mr. Aernout van der Bend**, managing director **Mr. Jeroen van den Heijden:** business asset manager
	THE HAGUE	**Regional authority of the Rotterdam - Hague agglomeration** **Metropolregio Rotterdam Den Haag** (MRDH).	**Ms. Tsveta Velinova**: in charge of European affairs **Mr. Jan Termorshuizen:** officer for transport / mobility
	UTRECHT	**Ector Hoogstad Architecten** (EHA) **Gemeente Utrecht** – public authority of the City of Utrecht	**M. Ector Hoogstad,** Chief architect EHA **Ms. Romy Berntse**, Project leader **Ms. Christien Rodenburg**, Senior mobility officer for the City of Utrecht
FRANCE	GRAND PARIS, ILE DE FRANCE	**"Vies mobiles" Forum**	**Mr. Christophe Gay**: director of the "Vies mobiles" forum (VMF) **Ms. Sylvie Landrièvre:** co-director of VMF. **Mr. Bernard Emsellem**: president of VMF
		Société du Grand Paris (SGP)	**Ms. Lucile Leblanc**, director of urban planning and metropolitan strategy department, Ile-de-France Regional Authority. **Ms. Chantal Jouanno**, vice-president in charge of planning and environmental issues, Ile-de-France Regional Authority. **Ms. Séverine Madura**, prospective and innovation division, urban planning and metropolitan strategy department, sustainable planning unit. **M. Bernard Kirsh, P**rojet manager (Ref. Line18) **Ms. Gaelle Pinson,** Digital Project. **M. Julien Peyron,** Executive director of the Public spaces and intermodality unit. **M. Benjamin Kliber**, in charge of innovation program. **Matthieu Drevelle,** AMO **(**Réf. Line 17N).
		STIFF, Cellule intermobility	**M. David O'Neil,** Head of the Service policy department – Directorate of Operation
		CVT ATHENA* /CNRS – CGI** Group of experts ("impact of self-driving cars on the Grand Paris project") *Consortium de Valorisation des sciences humaines et sociales ** Commissariat au Grand Investissement	**M. Hervé Zwirn,** Executive director of CVT Athena **M. Louis Schweitzer,** General Commissioner of the CGI
		"Porte-à-Porte" - Research unit of the French national railway company SNCF	**M. Hervé Richard**, director of the "Porte-à-Porte" research unit.
		SAFRAN Innovation – AAA research and innovation unit Aeronautics, Automation, Automatics	**Ms. Marie Privat**, advanced programs manager

		Mission des Transports Intelligents **MTI : MEEM - DGITM / IFSTTAR + LAET** **Stratys,** Council foresight, strategy and performance management (project Robomobile)	**M. Louis Fernique,** Chief Project of Mission Transports Intelligents **M. Christian Long**, in charge of strategic prospective
		EXID Assistance aux Projets, innovative transport solution provider (Paris)	**M. Régis Coat,** Project manager for 'Taxicol' autonomous minibus system
	SAINT TIENNE	**Group MICHELIN** Advisory Board "HeArt of Mobility"	**M. Emmanuel Mussault,** Chief Project manager
	GRENOBLE - LYON	**SNCF Gare & Connections** (Lyon)	**Ms. Audrey Risicato,** in charge of communication for projects and construction sites, Lyon office
		Laboratoire Aménagement Economie Transport (LAET) – Research unit for Transport Planning and Economy (Grenoble) **CityLib by Ha:mo** – operator of carsharing services in Grenoble Toyota Motor Europe (Paris)	**M. Olivier Klein,** Deputy director, engineer TPE **Ms. Corinne Breyton, i**n charge of the « new mobilities » programme **Mr. Patrice Axel Debus,** Project leader (EDF) **Mr. Rody El Chamas,** Manager
	LA ROCHELLE	**City of La Rochelle** **Proxiway (**Transdev group – manager of the 'Yélo' network)	**Mr. Jacques Mollard,** Former director of Technical services department, City of La Rochelle **Ms. Anne Chané**, Proxiway agency's director for La Rochelle
	BREST	**Brest Urbanism Agency** **Brest Métropole Aménagement** **Brest Metropole & Ville**	**Mr. Benjamin Grebot**, Director. **Ms. C. Guiheneux**, General Director. **M. Alain L'Hostis,** Direction of Patrimoine Logistique
GERMANY	BREMEN	**Department for the Environment, Construction and Transport** - Der Senator für Umwelt, Bau und Verkehr Fachbereich Bau und Stadtentwicklung	**Ms. Rebecca Karbaumer**: manager for local and European projects **Mr. Michael Glotz-Richeter**: in charge of developing sustainable mobility in Bremen
	BERLIN	**Berliner Verkehrsbetriebe (BVG) -** Berlin public transport authority **Technical University of Berlin -** CHORA City & Energy **Technical University of Berlin**, Mobility and Space research unit, Centre for Technology and society **Fraunhofer-Institut, Mobilitäts- und Stadtsystem-Gestaltung -** Shared Systems Design research unit	**Mr. Ruppert Stuwe** and **Ms. Rebecca Hagenow**, Department of Strategic planning and business development **Mr. Raoul Bunschoten**, Prof. of Sustainable Urban Planning and Urban Design **Mr. Wulf-Holger Arndt**, Professor, head of "Mobility and Space" research unit. **Mr. Michael Abraham**, researcher at the Mobility and Space unit **Mr. Michael Schmitz**, engineer, researcher
SWEDEN	GOTHENBURG	**Swedish national institute for Environmental Research** (IVL Svenska Miljöinstitutet)	**Ms. Åsa Hult**, advisor for mobility issues (formerly worked on the "Ubi Go" project)
		Public authority of the City of Gothenburg	**Ms. Malin Andersson**, head of the International Affairs department at the Transport Administration of the Gothenburg city authority
		Public authority of the Västra Götaland region (Västra Götalandsregionen)	**Mr. Jörn Engström**: civil servant, employed at the Department of strategic transport planning
		Public authority of the Västra Götaland region (Västra Götalandsregionen) / **Chalmers University of Technology**	**Mr. Göran Smith**: engineer, doctoral student, holds an industrial contract between Chalmers University of Technology and the Regional Authority Västra Götaland
		Lindholmen Science Park.	**Mr. Gunnar Ohlin**: leader of « ELMOB » project for electric and shared mobility
	STOCKHOLM	**Intermodes** - organisation for the promotion of intermodal mobility solutions	**Mr. François Gigot,** director of Intermodes

JAPAN	TOKYO	**Toyota Motor Corporation** Ha:mo Business Planning Dept. - ITS Planning Div. Connected Company	**Ms. Yukiko Homma,** IT engineer for transportation system. Group Manager -IN charge of Ha :Mo in Grenoble, then and now in Tokyo
		GIKEN Tokyo Head Office Construction Design & Planning Group Giken Limited	**M. Tsunenobu NOZAKI,** Department leader **M. Satoshi Kamimura,** International Construction Design
		O-path Meguro Ohashi – Green junction	**Dc. Yoji HAYASHI**, architect
		Eco-Mo Foundation	**M. Tetsuo Akiyama**, Prof. University Chuo Research and Developement Initative -Urban Environment and Transportation Planning for Aged Society. **M. Daisuke Sawada,** Section manager**,** Division for Promoting Accessible Transportation Infrastrcuture Okning and Survey. **M. Hideaki Okamoto**, Project Manager, Environnemental Transport Promotion Business **Dc. Soïchiro Minami**, assistant professor Kyoto University, Facy-ulty economic sciences **M. Kunihiko Naitoh**, Environmental Transport Promotion Division.
		Japan Railway JR Design Corporation	**Dc. Akihiko Kanai,** architect, Assistant manager Planning & Development Division
	TSUKUBA	**TSUKUBA ROBOTICS CITY** National Institute of Advanced Industrial Science and Techonoly (AIST) Smart Mobility Research Team (SMRT) Robot Innovation Research Center	**M. Dr Eng Osamu Matsumoto,** Principal Research Manager **M. Kohji TOMITA,** senior research scientist, SMRT **M. Dr. Naohisa Hashimoto,** senior researcher, Smart Mobility Research Team
	KASHIWA-NO-HA CAMPUS	**UDCK (Urban Design Center Kashiwa)** Kashiwa City Tsukuba District	**M. Hidetoshi OHNO**, Architect, Emeritus Prof. of the University of Tokyo-Principal. **M. Hiroya Mimaki,** vice president UDCK, Secretary General.
	NAGOYA	**Faculty of Health Sciences**, Nihon Fukushi University, Handa-City	**Daishi Sakaguchi, A**rchitect, assistant professor
		TOYOTA HOME : Atolis Park Kariya Expo site - Toyota Housing Corporation	**M. Mitsuru Yamane**, Executive General Manger, Product Development Div.
		Nagoya Institute of technology	**M. Keisuke Kitagaw,** Ass. Prof. Architecture Design City planning ,
	TOYOTA CITY	**TTRI Toyota Transportation Research Institute** - TOYOTA ECOFUL TOWN	**Dr. Eng. Hideki Kato,** Principal Research Engineer TTRI **M. Tetsuya Shibata**, Toyota City, Director, Eco-Model City Promotion Division Plannig Department **M. Masaya Douyama,** Urban Maintenance Department, Transportation Policy Division - Chief. **M. Tadahiro Kasuya**, Toyota City, Deputy Director, Advanced City Promotion Division Planning Department **M. Shinichi Imaeda,** Executive director, TTRI **Dr Ryosuke Ando,** Chief researcher at TTRI **Dr. Eng. Hideki Kato,** Principal Research Engineer TTRI