How railway stations can transform urban mobility and the public realm: The stakeholders' perspective

Alice Lunardon [a,*], Doroteya Vladimirova [b], Benedikt Boucsein [a]

[a] Technische Universität München, School of Engineering and Design, Munich, Germany
[b] University of Cambridge, Cambridge, UK

ARTICLE INFO

ABSTRACT

Railway stations are massive infrastructures through which people, products, materials, and energy flow every day. They usually gather a multitude of functions and provide a wide range of services to users based on their respective specific features. Thus, railway stations have the potential to play a critical role in reshaping our cities in a sustainable manner by facilitating intermodality, green and active modes of transport and logistics, and by gathering proximity services. In this reshaping process, implementing effective and seamless mobility, as well as the proximity of services, are key challenges. However, no urban transformation process can take place without the involvement and commitment of the respective stakeholders. This paper aims to form an understanding of the views these stakeholders have towards the potential of railway stations transformation, for the broad European context, to carve out first paths towards actually achieving that transformation. This study analyses a wide range of inputs and considerations made during a series of workshops held in 2021 by the EIT Urban Mobility where experts from a wide range of fields exchanged their experiences and ideas around the topics of urban mobility and public realm. In this process, railway stations emerged as a key player to meet the challenges of cities' sustainable development. After analysing their potential and exploring policy obstacles that are currently hampering such a transformation, this paper suggests a series of recommendations to better exploit railway stations, gained from the stakeholders' perspective.

1. Introduction

The railway station occupies a unique position in the urban environment as an important part of the city's utilities, a legacy of constant transportation development, and a link of the city to the rest of the world. Viewed spatially, the station is both a node of networks and a place in the city (Bertolini & Spit, 1998). To guarantee integration between transport networks and physical urban spaces, it is necessary to take account of this dual character. Also, stations must address both negative consequences directly caused by transport infrastructures on the urban environment and critical circumstances inherent in the urban context. A good balance of these factors can ensure stations' role as living spaces and focal points for a new urbanity, while improving the respective city's urban and socioeconomic quality (Conticelli, 2011).

Over the last fifty years, the railway station's potential as a viable contributor to the cities' sustainable development has been unnoticed. As a result, challenges and opportunities have gone ignored. The existing practice and theory of station development reflects an insufficient comprehension of the location's contradictory nature. In addition, rail-

way stations have often fallen in the gap between transport and urban agendas, as well as diverging responsibilities, being overlooked by urban planners and policy makers at local, national, and European level. As urban mobility still operates in a fragmented environment hostile to innovation, mobility systems continue to fail in meeting consumer expectations and to bring stakeholders together to collaboratively develop innovative mobility solutions and related policies (Audenhove et al., 2018). Railway companies, unreactive and cumbersome organisations, are not able to take the opportunity of realizing station's potential (Ecorys, 2012), and municipal institutions normally cannot influence their development.

Taking this unsatisfactory situation as a motivation and starting point, the objective of this paper is to analyse the views and the proposals of different stakeholders that participated at EIT UM Ideation Workshops in 2021, with the objective of understanding how stations can become a booster for cities' sustainable development.

EIT Urban Mobility is an initiative of the European Institute of Innovation and Technology (EIT), co-funded by the European Union. Its mission is to support positive changes in cities' urban mobility in order

to create more liveable places through collaboration between cities, industry, academia, research and innovation. In this context, every year the EIT UM organises workshops to gather all stakeholders to discuss about urban mobility and develop innovation.

2. Literature review

In the mid-19th century, rail became a key mode of transportation for goods and people in Europe. The construction of railway stations altered the urban landscape and they developed into important urban elements. The station was considered as 'volcan of life', 'palace of modern industry' and 'cathedral of humanity' (Dethier, 1981, p. 6), as well as a 'detector of urbanity', an object combining mobility and centrality (Duby 1985). However, after WWII, the railway industry declined to leave space to an increasingly car-based society (Wolmar, 2007). In this context, many stations had almost abandoned the outward signs of their civic vocation and their architectural structure of a forum of public life to progressively come to be seen as non-places, points of transit and nothing more (Detier, 1979). A huge dissociation between transport centrality and urban centrality appeared, making train stations invisible (Devisme, 2000) and rail transport losing demand (Gerkan, 1996).

Successively, in the last decade of the 20th century, fuelled by the introduction of high-speed and enhanced international rail services (HSR), stations retook importance in cities. Refurbishment projects of stations and their surroundings were launched, with the objective of increasing accessibility of station locations, in many cases leading to economic growth (Bertolini, 1998). New HRS stations have been used as a catalyst for urban redevelopment in a number of cities, and while there have been some obvious successes, the path to implementation has proven to be difficult in many other cases (Vickerman, 2015). These endeavours have been fuelled by a set of driving forces: the expansion and upgrade of rail infrastructure, the reduced demand for industrial space in central urban locations, the privatization of railways, the efforts to improve city attractiveness, the pursuit of sustainable development, and the new spatial dynamics of contemporary society. These factors have been coupled with varying emphases over time and between countries, resulting in three different ways of conceptualizing station area projects: 'property capitalization,' 'urban mega-project,' and 'transit oriented development' (Bertolini, 2012). The cases of London's St. Pancras and Paris' Gare du Nord stations are emblematic, as they have been the arenas for large-scale operations: St. Pancras' transformation boosted the renewal of the entire King's Crossroad area; and in Paris, the dismantling of a parking lot near Gare du Nord was the first phase of the entire area redevelopment (Riot, 2014). These buildings were renovated and given a central role as developers of the high-speed railway in Europe (Maillard, 2001). HSR stations have been a catalyst also in cities like Amsterdam (Zuidas), Brussels (Midi), and Madrid (Castellana), where the redevelopment projects brought a considerable economic growth (Loukaitou-Sideris et all, 2012). Hall and Banister (1994) argued that 'HSR will be the maker of some cities but the breaker of others'.

In intermediate cities, HSR opened up new opportunities by increasing their accessibility and interconnectivity, like the cases of Cordoba and Zaragoza in Spain, or Lille in France (Ureña et all, 2009). On the other hand, other cases demonstrate that HSR also facilitated territorial polarisation. For example, cities on the Shinkansen HSR line in Japan did not experience a shift of population or employment, but on the contrary, the line strengthened the economic role and primacy of Tokyo and Osaka at the expense of intermediate cities (Cervero and, Bernick,1996). Among the five most significant adverse effects of HSR stations are land speculation, gentrification and the consequential deracination of some residents and local businesses (Loukaitou-Sideris et all, 2012).

All this occurred at the same time of the partial transformation of many European railway companies from public authorities into semi-private or fully private organisations, giving them more financial autonomy and, consequently, a reduced obligation towards the public service they would offer (Wenner, 2020). This generated a strong commercial-

isation of stations (Hoffmann-Axthelm, 1996) while it also incentivized an active role of them in the urban development (Wenner, 2020).

Property booms had a role in the redevelopment of station areas, which were partially autonomous and partly tied to an explosion in office demand at certain places. The majority of station buildings have had a direct link to real-estate market conditions (Bertolini, 1998). Major urban development activities surrounding stations took place in conjunction with private players, giving birth to new financial models of public-private partnerships (PPP), like the case of Paris' Gare du Nord, where the French national railway company (SNCF) partnered with Altarea, a retail property developer (Schwarz, 2004). These redevelopments integrated a set of different activities inside and around stations by bringing new services into the scene. Multi-functionality was encouraged because it contributed to the station area's liveability and attractiveness (Bertolini, 1998). Integration of services brings to interaction, this is why tertiary sector firms prefer to be located around stations as they value the opportunity of interaction and exchanges that the stations can bring, especially if it is into a HSR network (Wenner & Thierstein, 2022). However, a more concrete, situation-specific commitment to multifunctionality would be needed by catering to both profitable and less profitable customers' interests (Bertolini, 1998).

From an urbanistic point of view, literature investigates also the effects that stations' redevelopments and the HSR advent have had on urban areas. A recent study shows that stations located in urban areas with available building land, coupled to a good local public transport network, easily conduct to new urban development (Wenner & Thierstein, 2022). Researchers have sought to examine such impacts of HSR in cities even though it is difficult to quantify how much development is directly attributable to a line (Givoni, 2006). But it is generally concluded that HSR cannot produce development by itself but can act as catalyst when other conditions are present (Lakatou-Sideris et all, 2012, page 10). Underlining this point, a study on Dutch cities showed that urban growth has not been a direct consequence of rail accessibility, as other factors played a more important role, such as operations of urbanisation in the areas, and the presence of multi-modality at the stations (Koopmans et al., 2012).

Cities have changed around stations. Many authors have identified the impact of stations on cities from an economic perspective as an attractive location for service industries (Pels & Rietveld, 2007; de Graaff et al., 2007). On the other hand, others authors have highlighted the negative changes brought by such redevelopments (Bertolini, 1998) by creating segregation and being drivers of injustices and urban inequalities (Camerin & Mora, 2019), like the case of Bilbao Ametzola's ancient railway station urban regeneration project. In such cases, to meet the goals of metropolisation and of internationalisation of the economy, municipalities started restructuring urban areas to implement commercial activities. Many railway lands have been demolished for the creation of quality spatial areas for a competitive economic claim (Sklair, 2017; Stein, 2019). In the Bilbao Ametzola project, which was characterised by the complete privatisation of the 11 hectares of railway facilities to be transformed in housing and commercial services, the aim was obtaining a first capital serving as a trigger mechanism to continue intervening in that territory with similar operations. This clear prevalence of the interests of the real estate system to the needs of an urban development (Camerin & Mora, 2019) can be also found in many other railway stations projects in Europe, like the case of Barcelona's Poblenou neighbourhood transformation for the Olympic games in 1992. Here, the redevelopments fuelled by the capital accumulation process transformed a large industrial and railway properties into a new urban district. These and other practices of neoliberal urbanism have been legitimized by public administrations, leading private actors to develop urban rent benefits by using urban land for a capitalist mode of production for the creation of a globalized city which, in many cases, led to the destruction of the social urban heritage (Camerin & Mora, 2019).

The competition for spaces, for users' attention, and for revenues create conflicts between stations' different functions (Zemp, 2011), which

led many authors to see the negative effects of those redevelopment operations in stations and urban surrounding areas. Many stakeholders are involved in such operations, and their goals are frequently at odds and, at best, disorganized. Existing organizational structures and governance often pose insurmountable impediments even when there is enough consensus on the aims (Bertolini, 2012). At the same time, railway stations hold considerable potential for their urban surroundings, as they are offering a variety of functions in society beyond the instrumental activity of facilitating train boarding (Alexander and Hamilton, 2015) that, "they are part of community life" (Edwards, 1997, p. 26). Railway stations are potentially significant and reusable heritage assets that provide new elements needed by local communities to enhance the sustainable development of territories (Llano-Castresana et al., 2013). Bertolini (1996), with his definition of stations as 'nodes' and 'places', described very well the ambiguous function of such infrastructures. On the one hand, stations are crucial 'nodes' in growing, diversified transportation networks. On the other hand, they identify a 'place,' a portion of the city where different kind of uses and forms take place, which may or may not participate to the 'node' functions of the station. The significance of 'place' was seen as an enabler of urban redevelopments which improved the station environment by other authors as well (Maillard, 2001).

Overall, integration of transportation and urban development in station areas has been, and continues to be, a difficult task. "Railways, like other modern communication and transportation systems, pose a theoretical dilemma. Do they alienate or destroy a sense of place...or enable new connections to be made? If the latter is the case, do these new experiences of place sufficiently compensate the loss of more traditional sensibilities?" (Bishop, 2002, p. 298). In this context, it is unsurprising that stations can be seen in a negative light, as a non-place (Alexander and Hamilton, 2015). In Augé's (2008, p. 63) work, the railway station is seen as an archetypal non-place, "a space which cannot be defined as relational, or historical, or concerned with identity".

The advantages of cultivating a sense of place indicate that communities have a transformational role in such contexts (Stratton, 2000, p.3), and it is now gaining momentum thanks to the new 'placemaking' practices which introduce a process of co-designing a city with its residents, allowing them to build the spaces they want while integrating the functions they require (Schneekloth, 1995). City administrations and urban planners gradually open up to placemaking. In the context of railway stations, examples such as the Scottish "Adopt a Station" concept for local communities have already been implemented (Alexander and Hamilton, 2015). They contribute to a reclaimed sense of place (Alexander and Hamilton, 2015), a concept that is central to contemporary society and works as the geographical component of the psychological need to belong somewhere, one antidote to a prevailing alienation (Lippard, 1997). In this context, it is possible to reconnect Bertolini's research on stations as both 'nodes and places' with the importance of placemaking activities at stations, and, in general, in urban areas.

The literature review illustrates that railway stations have mainly been studied from the perspectives of urban transportation and urban development, seen in many researches, as a positive aspect for the development of cities' economy. However, there is little research about the implications of such redevelopments on local communities and local economies. Also, there is little research on the impact of the uses and functions of stations' spaces in terms of urban-local development and the daily life of citizens. Furthermore, research gaps are identified in the understanding of stations as stable industrial infrastructures in cities, and how such infrastructures - through which materials, energy, water, and people flow - can offer a potential for enhancing resource utilization in cities. There are only few recent studies about the energy optimization at railway stations and energy reuse from the rail infrastructure to the station building, such as the reuse of the train braking energy, or the self-production of energy through photovoltaic panels. Building from these considerations, this paper aims at exploring such phenomena, from multiple stakeholders' points of views, to understand how to better use railway stations as 'nodes and places', aiming at boost the sustainable development of cities.

3. Methodology

3.1. The process

The EIT Urban Mobility created an 'Ideation Process' to assist its partners in developing new projects and ideas in urban mobility and public realm. In 2021, the entire EIT UM Community together with external organisations examined innovative ideas that matched cities, citizens, and industry's needs. To begin, a series of meetings with all stakeholders were conducted around urban mobility to determine the five core topics – called "Challenge Areas" – in which innovation is required: Active Mobility, City Logistics, Future Mobility, Mobility & Energy, Creating Public Realm. Second, a series of workshops were organized with all stakeholders on each one of the five Challenge Areas using the Cambridge's Value Creation Model (Vladimirova, 2019), which is a model developed at the IfM's Centre for Industrial Sustainability of the University of Cambridge by a group of researchers, including Dr. Doroteya Vladimirova who assisted in the workshops. It is based on a structured and visual method to identify 'uncaptured value' in the form of unsuccessful value exchanges: value missing, destroyed, surplus, and absent which are examined through the eyes of each stakeholder. This method enables organisations to work together in ways that increase value and deliver positive impact, as it explores the different values with the objective of aligning stakeholders' interests and needs while developing sustainable projects.

Following the steps of the Value Creation Model, the Challenge Areas served as the workshops' "unit of analysis" (main discussion topics). Six sessions have been performed, once per each Challenge Area, with the exception of Future Mobility that was performed in two sessions. Participants were divided into "stakeholder groups" based on their type, expertise, and areas of interest (e.g., city administrations, citizens, environmental experts, railway companies and transport operators, local businesses, etc.). To ensure accurate data collection and qualitative outputs, attendees' inputs were collected throughout the workshops in an interactive platform that allowed numerous participants to support the discussion with written notes and map the debate on its course. Participants from each stakeholder group were assigned to a separated virtual room to discuss the topic from their stakeholder's point of view. Afterwards, a conclusive discussion of all participants took place in a plenary virtual room, where new ideas and projects were developed.

The total amount of participants per workshop were around 30–40 people. Stakeholders' groups were composed by 5–7 people for a total of 5–6 groups. In all workshops, stakeholders' groups were the following: Cities (for city councils' representatives from different European cities, or organisations that work for local municipalities); Citizens (including experts, sectorial organisations representing the interests of users and citizens, and universities); Environment (including experts and researchers); Public transport and Railway Stations (including railway stations companies, public transport companies, researchers experts in railway stations); Mobility Providers (especially for private companies and start-ups from the sector); Energy Providers (only in the workshop on Energy – including experts, start-ups, energy companies); Local Businesses (only for the workshop of city logistics – including representatives of local commerce). Stakeholders that participated to the workshops were all partners from the EIT UM community from public institutions and municipalities from over 20 European cities, industry, start-ups, NGOs, and Universities (Our partners - EIT Urban mobility) and additional external organisations as follows:

- International sectorial organisations and NGOs: Placemaking Europe, European Cyclist Federation, Walk21, Fondazione Innovazione Urbana, Greencity, C40, BIDs Belgium
- European organisations and bodies: ETP ALICE, Shift2Rail

- Start-ups: VOI, Citywayfinding, Geovelo
- Other private organisations: Archipel.co, Trivector
- Railway Companies: SNCF (french national railways), PKP (polish national railways), FSI (italian national railways), SBB (swiss national railways), ProRail (dutch national railway infrastructure managers), DSB (danish national railways), FGC (catalan railways).

Workshops results were utilized to further refine ideas developed during the sessions, and then published into an online tool that all participants could use to create new projects. All these initiatives were designed to lay solid groundwork for the EIT Urban Mobility Call for Proposals, an open competition to create innovations on urban mobility.

3.2. Data analysis

The data gathered from the workshops was analysed in two stages. To begin, all inputs from all groups were analysed and summarized to form the first section of the findings, which included a broad overview of the themes discussed in each Challenge Area. Second, an examination of railway station-related topics was conducted with the objective of developing this research. Many European railway companies participated in "railway stations stakeholders' groups," which were then mixed up, allowing municipal administrations, researchers, sectorial associations, and mobility and energy providers to join the discourse.

The workshop data was evaluated to simplify the identification of recurring inputs in order to extract the most relevant themes and surprising findings (Breen, 2006), with internal compliance checks and cross comparisons properly taken into account. The most essential themes mentioned regarding the Challenge Area, the most notable quotes, and any surprising results were all included in the input analysis. By applying a colour code to each topic addressed and then analysing which colours were most frequent, axial coding methodology was used to identify the most essential themes discussed. This investigation revealed how important train stations are for urban mobility and its transformation.

The following factors were used to determine the dependability of participant inputs: (a) the extent to which participants agreed/disagreed on problems; and (b) the frequency of participant opinion shift during the conversation (Breen, 2006). The most notable comments are included in the findings and allude to particular assertions made by a participant on which all of the other participants agreed.

4. Findings and discussion

This chapter firstly explains the contents treated in each workshop (the Challenge Areas), then introduces the main findings by continuously making a link between the Challenge Area and the topic of railway stations. Secondly, it discusses the results by illustrating a series of concepts that demonstrate the importance of railway stations in urban planning and transport practices.

4.1. Description of the contents

'Active Mobility' is understood as a regular physical activity undertaken as a mean of transport, such as travel by foot, bicycle, kick-scooters, and the use of them mixed with public transport. Supporting the modal shift towards active mobility requires a range of different measures to be implemented in cities, not least the allocation of space to allow for safe and accessible solutions for these modes. Still many obstacles to achieve increased active mobility exist in European cities, mainly due to decades of car-centric planning that have created organisational and cultural barriers ("EIT UM Challenge Areas", 2020).

'Future Mobility' is an umbrella-term, developed for indicating all the solutions developed or envisioned with the aim to improve the flow of people and goods within urban areas. It is crucial to understand that future mobility is not built on solutions centred around cutting-edge technologies but encompasses a portfolio of various, human-centred approaches – while a purely tech-driven way of looking at, and governing

the transition, brings confusion and misunderstandings to public discussion and the way citizens imagine the future of the mobility sector ("EIT UM Challenge Areas", 2020).

The sector connecting 'Mobility & Energy' is currently undergoing a large-scale transformation. New solutions are absorbed and tested, existing ones upgraded, and cutting-edge technologies of the future anticipated. Some of the challenges are real bottlenecks and visible every day on the streets of European cities – rising demand for public e-charging points or rapid increase in the number of e-vehicles. At the same time, the growing market of renewable energy production and storage remains decoupled from the transport ("EIT UM Challenge Areas", 2020).

'Sustainable City Logistics' is about connecting the methods of fast deliveries of goods and food in cities with the ways citizens can collect them in a environmentally sustainable, comfortable, and time-efficient way ("EIT UM Challenge Areas", 2020).

'Creating Public Realm' is a Challenge Area focussed on the development of liveable public spaces connected with mobility. Public space represents a complex urban fabric confronted by various competing demands from public and private stakeholders. Dialogue and efficient governance models for public space are key to preventing potential conflicts and ensuring high quality of it ("EIT UM Challenge Areas", 2020).

4.2. Main findings

Levels and culture of active mobility differ throughout Europe, but as a common challenge is the adaptation of the existent mobility infrastructures to the new mobility services popping up in cities. But, policies for encouraging people to switch from cars to active modes of transport are still too weak, combined with a lack of positive narratives, creating discouragement among citizens as well as the still too high number of accidents between cars and active mobility users. Quantification of the benefits of walking and cycling in citizens' health still lacks consistent methodologies and is not included into transport decision-making. The physical and mental health impacts of active mobility need to be showcased to encourage people and also employers to the use of active modes of transport.

In addition, many cities lack of appropriate infrastructures. A study made in Helsinki shows that home location in a pedestrian zone or near a green area and higher proportion of cycling and pedestrian networks contribute to higher levels of commuting physical activity (Mäki-Opas, 2016), highlighting the importance of having appropriate infrastructures to enable citizens to switch from cars to active mobility modes. Improving the efficiency of a single trip made with more than one transport mode, offering travellers a seamless journey, it is crucial for enabling intermodality. This requires the creation of integrated transport systems through the harmonisation of different transport services and modes. Many cities have installed sharing bike systems that can be used by citizens at an affordable price. But, due to the high maintenance costs of such systems, these offerings seem not to be rentable for the municipalities. Consequently, this leaves the floor to private companies that, on the other hand, municipalities struggle in controlling. And in both cases, for maintenance and charging of electric vehicles such as bikes, kick-scooters, but also sharing cars, providers spend too much effort and energy. Trips back and forth with vans for repair damaged vehicles invade the streets and generate additional pollution, as well as trips for recharging electric vehicles far from the parking spot. In this context, railway stations, being the departure and arrival points of public transport in-and-outside cities, and as an aggregator of different mobility modes, could host all these services, thus becoming an enabler of intermodality.

For sharing mobility, in many European cities, there is often an uneven distribution of providers in stations' surroundings, which creates a network coverage with gaps and long walking distances. A participant from a sectorial transport organisation said: *"Too many mobility devices – competing between them – are currently present in the urban scene, which privileges individualism to the detriment of a social culture of mobility"*

(Video n.23, 04/02/21, min.28). Therefore, many people choose to possess personal mobility devices and carry them on the public transport. But taking bikes on trains, buses, and metros is often limited to foldable bikes and excluding peak hours when people might need it the most. The lack of bicycle parking around stations, especially in south-European cities, represents an impediment for citizens to switch from cars to public transport. In north-Europe, instead, where the bike culture is massively diffused, bike parking around stations support effective intermodality – like in Rotterdam Central Station and Utrecht Station where huge facilities for personal mobility devices have been constructed underground offering in this way an accessible and seamless commuting to travellers. On the other hand, in such places bicycles often invade streets and there is a need of finding innovative ways of parking.

Facilities for enabling active, sharing, and micro mobility do not concern only parking spots for these devices, but also charging stations for public and private electric vehicles.

Cooperation between public-and-private stakeholders is crucial, together with a proper financing for innovative solutions. A participant from a railway company said: *"Proper financing instruments are missing, especially from the public side"* (Video n.1, 20/01/21, min.1:07).

Railway stations are the connection point between private, shared, and public transport. Stations managers, public transport operators, and municipalities lack of data about trips of travellers on private and shared mobility devices, which leads to missing opportunities for them to know users' needs and trends. Private mobility operators do not share data with public institutions so that they are not able to provide travellers with an appropriate transport offering. Additionally, a lack of ticketing integration between all transport offerings do not facilitate seamless journeys for users. All these factors make that "Mobility as a Service" (MaaS) cannot be effectively implemented. A participant from the group of stations said: *"An effective MaaS should be based on open platforms supporting collaboration between companies and stakeholders and should also integrate other services related to mobility offerings, such as bike parking or other facilities that users can find inside and around stations"* (Video n.1, 20/01/21, min.37). To meet the growing expectations of society in terms of faster-commuting times and smarter commuting ways, the topic of MaaS must be brought to the forefront. Its goal may be expressed as *public but personalised*. Big data and machine learning should be better embedded in the strategic planning to promote effective transport development. But in parallel, as an opposite tendence, industry is developing new technologies for cars enhancing the comfort for vehicle owners, which incites people to continue use cars. Also the pandemic has brought to the preference of private vehicles like cars, instead of continue using public transport. The pandemic that has made loss trust in public transport, therefore, a better use of railway stations as nodes and places could probably make people regain trust in public transport and sharing mobility. MaaS solutions can represent a significant lever for the future of mobility, especially in guiding people through the stations and their surroundings, to find the services they need and the mobility offering. As an example, the public transport operator of Warsaw (ZTM) is currently dealing with the development of MaaS solutions for railway stations to enhance intermodality. In Milano, the public administration is developing a MaaS application that integrates all public and private mobility modes, with all options available in the app. Looking at future further developments of MaaS, a participant of the Future Mobility workshop proposed a new concept of '*selling mobility management instead of selling single trips*' where users could find both transport services and all the other daily services they need that require ticketing, while also including their working and personal calendars to pre-calculate trips time.

The central point of almost all discussions in the workshops has been the public transport, which seems to be crucial to achieve the 'mobility of the future' that the stakeholders envision. What is currently working well in public transport systems, is the fact that operators can handle very complex technological systems. Such knowledge should not be wasted. Industrial capabilities are there, but still not used effectively to satisfy the market and the social demand. Public transport is the backbone of transport to sustainably and inclusively move large numbers of people. Its assets are going to be redefined and adapted in light of future challenges. While technology enables a smooth integration of different services to provide seamless experience, it is a non-technology task that is needed to rethink spaces and assets, optimizing resources, avoid the multiplication of efforts and the waste of resources, and to develop synergies between investments. A participant from the group of cities said: *"Innovation is not yet seen as an opportunity to gain understanding of all stakeholders"* (Video n.1, 20/01/21, min.55).

As big industrial plants located in the hearth of cities, railway stations represent a node of networks of people, materials and energy passing through them. Such resources should not be wasted, especially when it comes to energy as it is one of the main topics on the top of all cities' agendas. Transport and urban mobility need to become energy efficient, and the current situation in Europe is mostly divided into two scenarios. First, Northern European countries host public charging stations in their cities, but they are not sufficient to meet the current demand. Second, Southern European countries are most populated by private charging points which are not well developed and not sufficient for the demand either, but in any case overloading public grids. Additional energy injected to the grid should be produced locally and in a sustainable way. A participant from a start-up said: *"Cross-charging point operators' collaboration is missing, and the charging infrastructure is not centralised, which is a waste"* (Video n.29, 10/02/21, min.31). Therefore, solutions promoting smart local energy generation elements and integration of such connected elements into the already built-in distribution grid are needed, and railway stations could be a good candidate for local production as they are nodes of energy networks, where flux of energy can fuel trains, station buildings, and urban mobility devices. Thanks to these characteristics and to their crucial positioning in the heart of cities, stations should be seen as an asset to combine energy production with socially inclusive and energy efficient mobility. There are large unused capacities in off-peaks for energy coming from train brakes in railway stations which represents an underuse of their potential. Regenerative braking from trains is an energy recovery mechanism during braking that converts the kinetic energy into electrical form (Akbari, 2021). A participant from a start-up said: *"There are no e-vehicles charging during the acceleration or braking time of a train"* (Video n.31, 10/02/21, min.36).

As the public energy networks are already overwhelmed in many cities, the energy that the station can hold and eventually produce, could directly fuel electric vehicles avoiding overcharging public networks. Systems integration and smart grids implementation require long term planning as well as coordination with the electric grid providers and other key value chain stakeholders, which is not yet happening in European cities, as many investments promote models with the shortest return on investment periods. There exist also other ways to balance the supply-demand equation with an emphasis on sustainability, most notably decentralized energy storage (batteries). But for the integration of such technologies into urban areas, it would be necessary to free up space to destinate to such storages, which is not always feasible, especially in dense cities. Moreover, costs of such infrastructures are difficult to estimate, and the process to install them is long. For battery storage, the suitability of using second-life batteries and battery recycling policies was identified to reap the benefits of local renewable energy production (e.g., photovoltaic panels - PV), that even in this case could be done at railway stations, for instance in their rooftops or in the rooftops of train platform shelters. PV requires proper management and monitoring, especially in its strategic points or at peak hours where a high concentration of moving passengers puts additional stress on the network. Data integration and analytic tools can satisfy these needs, but require a proper collection, analysis, storage, and management. Providing a structured system for real-time visualization is a challenging task, but of key importance when talking about energy interventions for the mobility sector.

While awareness of optimization of energy consumption is rising among European railway stations' managers, the lack of collaboration between stakeholders represents an obstacle to innovation. Some countries are making progress, like in the Netherlands where solar panels have been installed on the rooftops of stations, and the energy produced is managed by the public energy supplier that then use it to fuel stations but also other public transport modes, such as the metro. Station managers closely collaborate with the public energy provider to optimize energy efficiency. Each station is connected to the public grid, and they are looking if it is possible to reduce the number of connections in order to easier re-use the energy produced by solar panels installed on the stations' rooftops. This would be enable stations to locally produce energy and use it, while discharging the public energy network. Nevertheless, a concrete connection between stations' energy production and the fuelling of e-vehicles for urban sharing mobility is still missing. The city of Helmond denounces a lack of smart grids and a lack of charging solutions for all e-vehicles. A participant from the energy infrastructure industry said: *"There is still a lack of interoperability between systems and grids, and public authorities still cannot monitor the demand of the infrastructure to provide additional resources on spot"* (Video n.31, 01/02/21, min.48). Innovative solutions to develop such concepts must think about the most appropriate way of fuelling these spots to optimize costs and ensure supply continuity. To do this, the charging demand prediction at stations should be improved and its data properly collected.

Talking about lack of interoperability, in the urban mobility panorama, there is also another sector that suffer of such a lack: urban logistics. Currently there is poor cooperation between delivery companies, which is hampering trips optimisation. In such strongly competitive and customer-oriented market, there is no incentive either for delivery companies to introduce sharing economy practices into operations, potentially scarifying market shares and delaying deliveries. Due to the pandemic and the new consumption trends, the exponential increase of food and goods delivery has led to the rapid multiplication of trips in cities as well as the multiplication of delivery points (Hess, 2021). A participant representing local businesses said: *"Habits that people are taking by compulsively buying goods online are increasingly damaging local commerce by privileging global chains that actually have more efficient infrastructure and use of data"* (Video n.7, 27/01/21, min.17). Incentives for people to shop local are low, and local businesses lack cooperation in competing against global chains. While this emerging situation creates new jobs, business, and helps citizens in making their daily life more time-efficient, authorities are reporting collateral effects: poor condition of employees, more trucks congesting and polluting urban areas, and reducing the spaces for other traffic participants. Therefore, solutions must be found to optimise trips, for instance by combining delivery options, and to make this sector environmentally sustainable while also inciting citizens to shop local.

Policies and regulations are outdated and city administrations don't have access to data to be able to effectively organise urban logistics and gain visibility on the processes. The use and management of the entire logistic infrastructure is therefore too fragmented. A better exploitation of data could enable better optimisation of resources and capacities, but the current lack of coordination between stakeholders, as well as lacking regulation, makes the system inefficient and unsustainable. To address this issue, many cities are creating a zero emission zone in the centre town where new regulations hamper the entrance of polluting vehicles, giving more space to electric and green vehicles (e.g. cargo bikes, e-trucks), which are also smaller and can access small streets. For instance. the city of Eindhoven has created an hub at the entrance of the city around the main train station to collect materials and then distribute them by green vehicles into the city. The city is also thinking about new policies to stimulate the use of the hub by all logistic services, as it is currently mostly used by the city's own projects.

In the spatial context, city logistics have been discussed from the viewpoint of channels of goods distribution. Next to roads there are waterways and railways, including underground networks that are cur-

rently underused. If thinking about the opportunity of exploitation they could offer, urban underground, tramways, and trains are currently only set for passengers' transport, whereas they could combine both passenger and freight, especially when they run half-empty. In addition to new uses of public transport infrastructure, a breakdown of large warehouses into micro hubs would be an opportunity to significantly improve network resilience. Some European cities are already working on the creation of logistic micro-hubs, like for example, the 'city depots' in the Netherlands that gather goods and then dispatch parcels in the neighbourhoods by cargo e-bikes. In Madrid, smart lockers that people can easily access are popping up in some areas. In Greece, the macro consolidation centres are coupled with low emission fleets for the last mile delivery. The problem of all these systems is that they have high costs of maintenance and management, which can represent an obstacle to many cities for their implementation. A participant from a research institute said: *"Holistic planning is missing, and business models for new solutions are not yet well defined"* (Video n.8, 27/01/21, min.49). Thus, efforts should be joint to optimize the creation of such solutions.

In this context, railway stations could offer the opportunity to link freight transport with last-mile deliveries thanks to their central urban locations and direct connections with the rail network, improving the logistic chain as pivotal points between the city's peripheral and urban areas. A participant from a railway company said: *"For instance, goods arriving to the airports could be delivered in the cities by train and arriving to the stations they can then be dispatched in the city"* (Video n.8, 27/01/21, min.39). Currently, the only thing that some European railway stations implement are 'smart lockers', like almost all big SNCF stations in France. Offering 'hop-on hop-off' unmanned collecting points along the frequently travelled routes, smart lockers offer an alternative opportunity to home-delivery, avoiding at least the multiplication of trips for delivery trucks, while offering greater flexibility for both companies and customers. But, to decisively improve city logistics, much larger efforts have to be made. Stations have a lot of space on the underground that is currently used mainly for parking and maintenance. This space could be optimised and used for logistics and also for waste management. A good example can be found at the SNCF station of Marseille, where, in addition to waste management, they also produce energy through the waste treatment.

Adding an additional layer to the transport and logistics function, railway stations have the potential to become a 'one-stop service' for most of the needs that citizens have during their daily life. Opportunities for testing new solutions and raising awareness for behavioural change should be experimented. For instance, testing sharing mobility solutions and new models for their subscription combined with the available public transport infrastructure could be a lever for people to use public transport and sharing mobility instead of buying a car. Moreover, it is necessary to synchronize social activities and services with transport services. For instance, in Paris' St. Lazare Railway Station new permanent and temporary services for users are implemented, such as shops of local farmers. A good example of synchronisation of services and transport is the kindergarten installed inside the station. In this way, parents can drop-off children and then take the train to go to work. Changing behavioural patterns can be done by both pushing and pulling measures as well as new policies, and testing new services and activities.

The mobility of the future is not only about improving transport services, but also better managing public spaces in urban areas. Municipalities have a key role here since they own public space and bare high maintenance costs for the provision of basic services, including safety, accessibility, and connection. From this perspective, it is crucial that projects for public spaces are well coordinated internally, which would help achieving a systemic change in a long run. Some cities are already applying holistic approaches to take advantage of their cultural and historical background, for instance the design-culture in cities like Milano, or the "Superblocks" in Barcelona where streets for cars are transformed into spaces for active mobility and social activities by gathering a mix of uses, allow social interaction. In this way urban spaces become more

attractive. The objective is to achieve a healthier, greener, fairer, and safer public spaces favouring social relations and boosting local economy. In Milan, the organisation of multiple social events is as a way of living the city and moving around. These events are a showcase for the city, a first taste of car-free streets and zero emission areas to be developed. Similar initiatives can be found in Stockholm where, every year, a number of places are transformed into pedestrian streets, pop-up parks, summer and winter squares. Here, spaces are created for social activities, meetings and art, where people are encouraged to participate. One of the most important aspects that emerged during the workshop is that ensuring such vicinity and proximity is crucial for a more sustainable urban mobility, meaning that citizens have equal access to services and can avoid long trips. A participant representing citizens said: *"Time and energy are still wasted in commuting, as often the services that citizens need to access are far from their homes and job places"* (Video n.1, 20/01/21, min.44). To improve connectivity, services need to be brought to the vicinity. To this extent, emerging concepts like the '15-minute city' promote the access to proximity services at walking distance (Moreno, 2021). This concept became more popular during the pandemic when having services at walkable distance was essential for people. Such urban planning concepts like the '15 min city' implemented in cities like Paris and Milan, and '1 min city' in Stockholm, allow for a coherent implementation of proximity. In this context, railway stations were identified by participants as places with a great potential of bringing proximity and mobility services together.

Despite this, many cities still struggle with implementation of such planning concepts as per strict regulations and complex certification procedures that have a discouraging effect. One of the gaps highlighted during the workshop was the underuse of architectural know-how. A participant from a city council said: *"Cities are not applying the extensive existing architectural know-how to urban design practices"*. Another participant from another city council affirmed: *"This is because of a lack of cooperation between stakeholders and between the different departments in city councils"* (Video n.10, 17/02/21, min.26–28). Participants from industry and research entities have declared interest in deploying tactical urbanism solutions at their own cost, to be able to demonstrate their effectiveness to municipalities.

In this context, railway stations have been seen as a possible potential player in the development of 15-minute cities, as they could play a role here of mediation between the needs of public transport operators, the private mobility service providers that occupy the urban space, and the local communities that need to use the public space. Stations, as seen in literature, can be nodes and places (Bertolini, 1998) and gather network of transport while also offering their (public) spaces for relevant activities and services for city inhabitants.

Some railway companies are already taking a role in urban planning practices, like for example the French SNCF that is working closely with local governments to develop masterplans around French stations, but beside these specific examples, in European cities there is still a fragmentation between the transport infrastructure and the urban tissue, which leads to a barrier effect both within the station's building (barriers between transport uses and commercial uses) and the surrounding city. Cause of this is often due to physical boundaries between the station and the city's public soil, as well as a lack of coordination between both stakeholders. In addition, the time of use of the station – which is currently dependent only on the railway company's needs, and is consequently used only during daily hours – doesn't allow use of this place for other purposes at night, which enhance even more such a fragmentation.

In addition, participants have highlighted the fact that stations are still perceived without much reference to identity and cultural value, which makes difficult their "conceptual" transformation into centres of life and proximity. Before the emergence of the automobile, stations were closely connected to their urban surroundings, functionally and spatially knit into the adjacent urban fabric. But, as seen in literature review, most stations successively lost that function mainly due to the raise of cars' use, and their surroundings have been destinated to parking or other functions with no social either cultural value. A participant from a university said: *"Cultural value and identity is missing. The station could be a place with an identity as it is a public and shared space. The identity can come partly from the station itself and partly from its surroundings"* (Video n.15, 17/02/21, min.41). Therefore, new functionalities, more quality and features of public spaces are needed inside and around stations, to allow people to transit, work, meet, but also stay in these spaces. This would foster the sense of community and neighborhood that is currently missing. A participant from a research institute said: *"Currently, stations are not places where the people want to spend time or have activities – such as working, learning, enjoying the space – as they are only transfer points, for short stays where you feel obliged to buy something or leave"* (Video n.25, 04/02/21, min.18). A 'social value' is therefore missing, and the potential of a station as a 'social public space' - with no commercial sense - has not been considered yet. Stations, with a smart combination of mobility services with other auxiliary functions, can become the connection between the transport network and the public space of the city; they can potentially support sustainable behaviours among citizens and mobility users, while creating new opportunities for local businesses and services. For this to be achieved, in Poland for example, the national railway company (PKP) is developing a project around stations inspired on the Dutch idea of Woonerf (a good public spaces for pedestrians) by converting areas around stations into parks and public spaces to enable social interaction and give citizens spaces for their social activities.

4.3. Discussion

Changing travellers' modes of transportation from car to rail is a crucial European strategy (Brons et al., 2009) to improve public transportation, and terminal services quality is acknowledged as a significant factor affecting travellers' behaviour (Cascetta & Cartenì, 2014). In this context, the intermodal hub – like the railway station – is an important part of door-to-door travel, especially when it is well integrated into a network of hubs, as demonstrated in the literature review. It can aid in the development of public transportation by offering a way of connecting public transportation services to establish a network and improving mode integration and transfer (Hickman et al., 2015). Connecting public transport modes with the new fast-emerging sharing mobility and personal-mobility devices can improve intermodality (Doe, 2019), and this can happen at railway stations where multiple transport networks and a variety of transport modes can be found. As advocated by the TOD model in literature, the intermodal hub can therefore perform two key functions: a key element of the multiple-links public transport journey, and an enabler of surrounding urban areas' development (Hickman et al., 2015). However, the integration of transportation development with urban development and the coordination of related activities is a challenging undertaking. Literature demonstrates that, to successfully develop a TOD, a planning framework and a public-private funding strategy facilitating transportation and urban development are required (Bertolini, 2012). Many decades of modernist urban planning based on the implementation of different categories of activities in separated zones of the city (Sim, 2019) now make it difficult to redevelop urban areas in 15-minutes neighbourhoods and TODs. In 1961 Jane Jacobs, pioneer of criticisms to this model, raised the flag by perfectly describing how the separation of functions in cities led to a car-based scenario where people need to travel many kilometres to reach their jobs, commercial malls, and other services in and around the city, far from their residences. Today, fundamental changes are difficult to make as cities cannot adapt quickly and be rebuilt. A thorough examination of local planning documents may shed light on the role of local players and methods in enabling or regulating such development (Wenner & Thierstein, 2022). Despite the fact that many governments are eager to capitalise on accessibility advantages for urban growth, much remains to be done in terms of transit-oriented development.

Re-thinking railway stations as "multi-modal and proximity services hubs" could allow to sustainably move large numbers of people while boosting the compactness of the city by offering proximity. As illustrated in literature review, it seems important to understand through the analyses made so far by researchers, is that stations have a potential in urban regeneration (Lakatou-Sideris et all, 2012). If looking at stations as social infrastructures, instead of just transport infrastructures, it is possible to imagine them serving citizens in their daily life by integrating socio-economic activities while hosting active-and-micro mobility facilities such as parking, e-charging stations, and related services, facilitating in this way the modal shift. Additionally, if connected when possible with disused rails transformed into greenways for active mobility users (Rovelli et al., 2020), stations could become a node of active mobility network in cities. Intermodality can be enabled through stations also by including other mobility modes, and optimising existing resources: in stations where people still arrive by car, such car-trips could be shared with other users (e.g. car-pooling). Incentives to this could enable such a system if users are awarded when hosting other passengers during their trips. Systematically integrating such services in stations can enable citizens to use multi-modal combinations.

Factors that made the success in some intermodal hubs, like in Tokyo, are related to both public incentives for TOD's development (most importantly, a transportation policy that restricts automobile ownership and usage while actively promoting public transportation, as well as a land-use strategy that encourages construction near stations), and the business strategies promoted by the railway companies (Bertolini, 2012). Developing a sustainable multimodal system thus needs the removal of numerous impediments, which can only be accomplished through suitable policy frameworks that include public participation (Szyliowicz, 2004), which in parallel can also lead towards the creation of new business opportunities for stakeholders.

In addition, railway stations represent one of the most industrial structures that are still located in the centre of cities, supporting in this way the cities' functions as a complex facility (Ferrarini 2005). Consequently, they have a potential for serving the city and its inhabitants not only as a transport departure-arrival points, but also as valuable assets that may assist cities' transition to more sustainable production and consumption modes. They act as 'resources-optimizators' for logistics and material flows, and as 'greening engines' for energy production from different sources and the distribution to urban mobility. Studies and experiments have been done on energy efficiency and self-production at the station, but very few research connects such production with the fuelling of urban mobility devices. Regulations allowing such connections and energy infrastructure's optimisation are currently missing. A study made in France, investigates energetic concepts in order to store the braking energy of the trains with a stationary electrical saving system, and to reutilize it for the power supply of electric and thermal consumers or actuators in a railway station thanks to a microgrid (Galaï-Dol et al., 2016). In this study, the RATP (the Parisian urban railway operator) developed an experiment in which reutilises the braking energy from trains for the power supply of electric equipment in a railway station thanks to a microgrid. Results demonstrated that, due to differences in the existing equipment, it would be difficult to change all the already existing equipment into a station, as it generates high costs, but it can be interesting to forecast it for new railway stations concepts. The study is a first step to a multi physical micro grid, which is a trampoline to the micro grid and the urban living of the future when the micro grid will integrate many kinds of energy resources (Galaï-Dol et al., 2016). Another study that compares different types of energy supply for station buildings, shows that railway station loads can be supplied by grid, photovoltaic panels or energy storage systems. Electrical railway system can be charged by either utilizing regenerative braking energy, photovoltaic panels or grid. It demonstrates the relevant cost reduction when producing energy with such systems, and how the increase in photovoltaic panels size results in a significant decrease in daily operational cost of the smart railway station (Sengor, 2018). Such studies demonstrate that an organised system

may serve various loads from various energy sources in an efficient and cost-effective manner for the station, which can in this way become an energy-hub (Akbari, 2021) thanks to the high reusable energy potential lying behind the electrical railway system. Storing brakes energy and using it during daily consumption peaks would allow to help decrease carbon emissions while also lowering energy bills (Galaï-Dol et al., 2016). Consequently, it seems important to advance the research on these topics and discover new technologies, but this needs cooperation between stakeholders and a proper data collection and analysis.

When talking about resources' optimization, a more sustainable urban logistics chain might be accomplished by considering the possibility of railway stations as middle-point hubs in the chain, between warehouses located outside of cities and last mile delivery services. Stations would help the entire value chain in cutting journeys by optimizing the flow of goods by collecting goods more centrally but still in a fine-grained mesh, bridging the gap between freight transport and urban logistics. Also, combining train transportation with emissions-free parcel delivery through cargo bikes could help decouple neighbourhoods from vehicles while also addressing the curb-management issue. By doing so, the positive contribution to the energy layer is also expanded: fuel consumption is drastically reduced and replaced by energy, ideally from renewable sources, that may be produced at the station. Due to railway stations' central function, the supply-demand balance may be monitored and optimized. Simultaneously, the station can serve as a hub for logistical waste management, eventually also generating electricity from its treatment.

Development of TODs is not only about transport, but also about urban development around intermodal hubs. To enable sustainable mobility in cities is fundamental to work on 'proximity', as seen in the previous chapters, and logistic services are also part of such proximity. If primary services and shops are placed at a walking or cycling distance from inhabitants' homes, active and sustainable mobility is enhanced while environmental footprint is reduced, and time is saved in commuting. In addition, proximity promotes social interactions (Moreno, 2021), as advocated also by urban theorists like Jacobs (1961).

Mediating between transport and urban needs in the space of a station could help manage the urban and infrastructural development. Integration of services brings interaction between stakeholders, which facilitates exchanges and enable business (Wenner & Thierstein, 2022). As a node, the railway station must guarantee a seamless journey and a high quality space. As a place, it should have a urban centrality role, thus becoming part of the city through the development of mixed-use environments and services inside and around it (Conticelli, 2011). As advocated by Bertolini (1998) a more concrete, situation-specific commitment to multifunctionality would be needed when (re)developing stations, by catering to both profitable and less profitable customers' interests. Moreover, coupling transport functions with other socio-economic activities enable urban compactness, which is key for reduce consumption of resources and energy (Yin, 2015).

Nevertheless, obstacles to such stations' redevelopments are multiple. The most evident concerns property value which 'obliges' stations managers to rent its spaces to very high prices, often not affordable by local commerce and other kind of services. This was the consequence of property booms in the 1990s, where real-estate market conjunctures have had a driving relevance in most station projects (Bertolini, 1998). Consequently, small and local businesses and public services are excluded from these spaces. The involvement of new (public and private) stakeholders in the co-financing of stations' development should be explored, to be able to integrate local businesses offering proximity services while a better understanding of users' needs would also bring new business opportunities for all stakeholders. Co-funding mechanisms as well as the use of green and social bonds should be explored for launching or testing the funding of such new activities.

So far, research has paid little attention to stations and the urban design of their immediate surroundings as part of the urban transforma-

tion processes (Ponzini, 2013). Stations redevelopments in the 1990s, even though they were intended to improve rail transport and generating sustainable urban areas, often led to an economic polarisation and hierarchisation (Wenner, 2020; Chen & Hall, 2015; Garmendia et al., 2012; Vickerman, 1997), especially of local communities. But recently, the literature on urban studies has shifted from the idea of the transport infrastructure as an element that produces discontinuity with the urban tissue to an infrastructure that generates places for citizens while still creating urban continuity (Ferorelli, 2016), which represents an improvement and a fertile ground for giving the station a role of urban connector. As a result, stations can be used to generate such public linking areas while also allowing social interactions.

Building from these considerations, it seems crucial to understand how new uses of such areas could impact local communities and travellers. In this context, a response to can be found in the emerging 'place-making practices' that, through the co-design of such public spaces, would allow local communities regaining ownership of them, while implementing activities tailored to their needs. Customers and citizens - rather than transportation companies - can define which services must be offered; and transportation operators can just provide customers with an operating system they can utilize according to their needs.

As highlighted during the workshops, people do not move between stations; they move between activities. Consequently, if transfers between activities can be made easier, faster, more convenient, productive – and more pleasurable – then public transportation will likely be used for better, more diverse, and more frequent travels (Chen et al., 2014). To do this, it is necessary to understand what engages people in the design of public spaces, what draws them away from their everyday routines to generate value in these areas, and the station might be transformed into a place where people can have an experience. Currently, when people get to the station feel compelled to buy or leave. There are no services or activities where users are not required to purchase.

Thompson et al. (2012) observe how the railway experience is created through complex interactions between the railway and the people who use it. Because rail travel is a socio-technical system, social interventions may be required to preserve favourable experiences. As seen in literature review, the experiment conducted in Scotland where community groups and individuals have been invited to gardening activities inside some stations, demonstrates that the station has been appropriated as an extension of urban activities, making it a part of a larger community agenda to make a more meaningful place for visitors and residents (Alexander and Hamilton, 2015). Appropriation leads to an increased sense of ownership of the station. Adopters engender and create a sense of place as a result of their sense of ownership, which leads to emotions of responsibility and a vision of the future (Alexander and Hamilton, 2015). Through adoption, instead, citizens come to see stations more as community assets than transport hubs (Alexander and Hamilton, 2015). Thus, providing free-creative places for station users (such as the pianos already installed in many stations) could be part of a solution to understand what citizens need in that specific location. Obstacle to this is that stations are private spaces that need to be rented to generate revenues. Therefore, co-creating spaces inside and around stations is a challenge that needs policy adaptation and collaboration between private and public stakeholders.

5. Conclusions

The findings presented in this paper show that stakeholders around European railway stations see the potential of better using stations to improve urban transportation and related urban spaces, citizens' daily life, and city's resources optimization. To achieve this, specific topics needs to be investigated to generate new knowledge and industry achievements.

Analysing the role of the station as a public space dedicated to citizens is fundamental. Developing stations as spaces and infrastructures at the service of the public would imply transforming them into mobility hubs where both local and global businesses serve residents' demands and promote effective and sustainable travel. Urban policies and regulations, as well as stations governance, must be adapted. In this context, the position of the urban planner could be a change agent. However, in order to build cooperation among stakeholders, ideas must be tested and possible impacts analysed, to then build roadmaps for transformation.

Second, an upgrade in the utilization of the stations' energy infrastructure should be explored through experiments, as it represents a key asset for urban energy challenges. More in-depth research utilizing a data-driven strategy to generate an energy map and identify the most vulnerable spots, both within infrastructure and governance of railway hubs, can help develop unique solutions for stations' energy efficiency. Similarly, the circularity of resources moving through the station is vital for helping the city in its sustainable growth, such as greening urban logistics and waste chains. To create a regulatory adaption lever, tests of novel models of material and logistics management should be done.

Third, there is a need for a general overview of the value of such assets, from the station's construction to all assets that pass through it every day, to the value of its catchment area, not only from a financial standpoint, but also considering social values and environmental challenges that such innovations may bring.

As is the case in most transformation themes connected to sustainability, the transformation and better utilization of railway stations and their surroundings needs a concentrated, collective effort by all stakeholders involved. As shown in this paper, the paths for European railway stations are clear and the motivation of many involved actors is high; it is thus a strong argument for political actors to activate the existing potential and set transformation into motion.

As highlighted in the literature review, redevelopment of station areas is a challenging task where no single model has yet been found that can be applied to all situations. This is the case from both a planning perspective and a policy and governance perspective. The reason behind this is that each context has local peculiarities, different driving forces and obstacles. Therefore, as suggested by Bertolini (2012), an experimental attitude and a willingness to learn from both others' and one's own experiences seems essential to tackle such a challenge.

Building from these considerations, this paper represents the starting point of a wider research of which the next steps will be the study of the impacts of experiments in different stations in Europe that will be conducted in the following months. Three projects let by EIT UM with three different cities in Europe (Milano, Toulouse, and Madrid) will take place in railway stations contexts. They concern the development of intermodality at these stations and the construction of a model to be scaled up to other places. New services for micro-mobility and active mobility will be tested during 6–12 months at these stations, together with additional services for citizens and placemaking activities. During the test period, activities of involvement of local communities and users will be undertaken to observe and analyse the impact of such tests, while also collecting the feedback and ideas from citizens about the development of such models. The research will be based on these outputs.

Declaration of Competing Interests

a main topic for urban mobility field, she develops synergies between her work at the EIT UM and her academic research with the objective of improving the research and projects of the organisations that collaborate with the EIT UM, and at the same time, enriching her research by collecting data from the projects on railway stations that are developed within the EIT UM.

CRediT authorship contribution statement

Alice Lunardon: Conceptualization, Formal analysis, Investigation, Resources, Data curation, Writing – review & editing, Visualization, Project administration, Funding acquisition. **Doroteya Vladimirova:** Methodology, Validation, Data curation, Supervision. **Benedikt Boucsein:** Validation, Supervision, Formal analysis, Writing – review & editing.

Acknowledgments

References

Akbari, M. (2021). *Complexity and uncomplexity during energy injection* p. 2021. Ithaca: Cornell University Library arXiv.org.

Alexander, M., Hamilton K., (2015). A 'placeful' station? The community role in place making and improving hedonic value at local railway stations. 10.1016/j.tra.2015.09.006.

Audenhove, F., Smith, A., Rominger, G., & Bettati, A. (2018). The Future of Mobility 3.0, Reinventing mobility in the era of disruption and creativity. *Aurthur D Little Insights*, (March), 50.

Augé, M. (2008). *Non-Places: An introduction to supermodernity*. London and New York: Verso.

Bertolini, L., Curtis, C., & Renne, J. (2012). Station area projects in Europe and beyond: Towards transit oriented development? *Built Environment, 38*(1), 31–50.

Bertolini, L. (1998). Station area redevelopment in five European countries: An international perspective on a complex planning challenge.

Bishop, P. (2002). Gathering the land: The Alice Springs to Darwin rail corridor. *Environ. Plan. D, 20*, 295–318.

Breen, R. (2006). A practical guide to focus-group research. *Journal of Geography in Higher Education, 30*(3), 463–475. 10.1080/03098260600927575.

Brons, M., Givoni, M., & Rietveld, P. (2009). Access to railway stations and its potential in increasing rail use. *Transportation Research Part A: Policy and Practice, 43*, 136–149.

Camerin, F., & Mora, A. (2019). Regenerating Bilbao: From 'productive industries' to 'productive services'. *Territorio, 89*, 2019.

Cascetta, E., & Cartenì, A. (2014). The hedonic value of railways terminals. A quantitative analysis of the impact of stations quality on travellers behaviour. *Transportation Research Part A: Policy and Practice, 61*, 41–52.

Cervero, R., & Bernick, M. (1996). *High speed rail and development of California's central valley: Comparative lessons and public policy considerations*. University of California, Berkeley IURD working paper #675.

Chen, C., & Hall, P. (2015). High-speed trains and spatial-economic impacts: A British-French comparison on two scales: Intra- and inter-regional. In R Hickman, M Givoni, D Bonilla, & D Banister (Eds.), *Handbook on transport and development* (pp. 301–317). Cheltenham: Edward Elgar Publishing.

Chen, C., Hickman, R., & Saxena, S. (2014). *Improving interchanges. Towards better multimodal Hubs in the PRC*. Manila: Asian Development Bank.

Conticelli, E. (2011). Assessing the potential of railway station redevelopment in urban regeneration policies: An Italian case study.

de Graaff, T., de Groot, H. L. F., Rodenburg, C. A., & Verhoef, E. T. (2007). The WTP for facilities at the Amsterdam Zuidas. *Environment and Planning A, 39*, 2099.

Dethier, J. (1981). *All Stations: A Journey Through 150 years of Railway History*. London: Thames and Hudson.

Devisme, L. (2000). Villes en Gare. *FLUX Cahiers scientifiques internationaux Réseaux et Territoires Année, 39-40*, 123–128 2000.

Doe, J. (2019, Mai 28) Intermodality. https://www.eltis.org/glossary/intermodality.

Ecorys. (2012). *Competitiveness of the European Railway Supply Industry.*

Edwards, B. (1997). *The modern station: New approaches to railway architecture*. Oxford: Taylor & Francis.

EIT UM Challenge Areas (2020). Retrieved from https://www.eiturbanmobility.eu/innova tion/areas-of-innovation/

Fererolli, R. (2016). *People as infrastructure. Lo spazio pubblico della società in rete* Ph.D. Thesis. DAStU Politecnico di Milano.

Ferrarini, A. (2005). *Railway stations: from the Gare de l'est to Penn Station*. Milan: Electa architecture.

Galaï-Dol, L., De Bernardinis, A., Nassiopoulos, A., Peny, A., & Bourquin, F. (2016). On the use of train braking energy regarding the electrical consumption optimization in railway station. *Transportation Research Procedia, 14*(2016), 655–664.

Garmendia, M., Ribalaygua, C., & Ureña, J. M. (2012). High speed rail: Implication for cities. *Cities (London, England)*, (29), 26–31.

Gerkan, M. V. (1996). Renaissance der Bahnhöfe als Nukleus des Städtebaus. In MV Gerkan (Ed.), *Renaissance der Bahnhöfe: Die Stadt im 21. Jh* (pp. 17–63). Braunschweig, Wiesbaden: Vieweg.

Givoni, M. (2006). Development and impact of the modern high speed train: A review. *Transport Reviews, 26*(5), 593–611.

Hickman, R., Chen, C., Chow, A., & Saxena, S. (2015). Improving interchanges in China: The experiential phenomenon. *Journal of Transport Geography, 42*(2015), 175–186.

Hoffmann-Axthelm, D. (1996). Stadtunterfahrung: Zu einer modischen Wendung im Verhaltnis von Stadt und Bahn. In MV Gerkan (Ed.), *Renaissance der Bahnhöfe: Die Stadt im 21. Jh* (pp. 225–232). Braunschweig, Wiesbaden: Vieweg.

Jacobs, J. (1961). *The death and life of great American cities*. New York, NY, USA: Random House.

Koopmans, C., Rietveld, P., & Huijg, A. (2012). An accessibility approach to railways and municipal population growth, 1840–1930. *Journal of Transport Geography, 25*(2012), 98–104.

Lippard, L. R. (1997). *The Lure of the Local*. New York: The New Press.

Llano-Castresana, U., Azkarate, A., & Sánchez-Beitia, S. (2013). The value of railway heritage for community development. *WIT Transactions of The Built Environment, 131*, 61–72.

Loukaitou-Sideris, A., Cuff, D., Higgins, T., & Linovski, O. (2012). Impact of high speed rail stations on local development: A Delphi survey. *Built Environment, 38*(1), 51–70.

Mäki-Opas, T., et al., (2016). The contribution of travel-related urban zones, cycling and pedestrian networks and green space to commuting physical activity among adults – a cross-sectional population-based study using geographical information systems. *BMC Public Health, 16*(2016), 760. 10.1186/s12889-016-3264-x.

Maillard, M. (2001). Three new French TGV stations. *Japan Railway & Transport Review, 28*, 26–28.

Moreno, C., Allam, Z., Chabaud, D., Gall, C., & Pratlong, F. (2021). Introducing the "15-Minute City": Sustainability, resilience and place identity in future post-pandemic cities. *Smart Cities, 4*(1), 93–111. 10.3390/smartcities4010006.

Pels, E., & Rietveld, P. (2007). Railway stations and urban dynamics. *Environment and Planning A, 39*, 2043–2047.

Ponzini, D. (2013). Branded megaprojects and fading urban structures in contemporary cities. In G Del Cerro Santamaria (Ed.), *Urban megaprojects: A worldwide view* (pp. 107–129). New York: Emerald.

Riot, E. (2014). A European perspective on the planning of major railway stations: Considering the cases of St Pancras Station and Paris Gare du Nord. *Town Planning Review, 85*(2), 2014. 10.3828/tpr.2014.12.

Rovelli, R., Senes, G., Fumagalli, N., Sacco, J., & De Montis, A. (2020). From railways to greenways: A complex index for supporting policymaking and planning. A case study in Piedmont (Italy). *Land use Policy, 99*(2020), Article 104835.

Schneekloth, L., Shibley, R. (1995). Placemaking: The art and practice of building communities.

Schwarz, G. (2004). Le monopoly des gares parisiennes. *Les Echos, 19245*, 27.

Sengor, I., Akdemir, H., Erdinc, O., & Catalao, J. (2018). Energy management of a smart railway station considering regenerative braking and stochastic behaviour of ESS and PV GENERation. *IEEE Transactions on Sustainable Energy, 9*(3) JULY 2018.

Sim, D. (2019). *Soft city*. Island Press.

Sklair, L. (2017). *The icon project: Architecture, cities and capitalist globalization*. New York: Oxford University Press.

Stein, S. (2019). *Capital city. Gentrification and the real estate state*. London- New York: Verso.

Stratton, M. (2000). *Industrial buildings: Conservation and regeneration*. Taylor & Francis.

Szyliowicz, J. (2004). Decision-making, intermodal transportation, and sustainable mobility: Towards a new paradigm. *International Social Science Journal, 55*(176), 185–197 2003-06.

Thompson, K., Offler, N., Hirsch, L., Every, D., Thomas, M. J., & Dawson, D. (2012). From broken windows to a renovated research agenda: A review of the literature on vandalism and graffiti in the rail industry. *Transportation Research Part A: Policy and Practice, 46*(8), 1280–1290.

Ureña, J. M., Menerault, P., & Garmendia, M. (2009). The high-speed rail challenge for big intermediate cities: A national, regional and local perspective. *Cities (London, England), 26*(2009), 266–279.

Vickerman, R. (1997). High-speed rail in Europe: Experience and issues for future development. *The Annals of regional science, 31*, 21–38.

Vickerman, R. (2015). High-speed rail and regional development: The case of intermediate Stations.

Vladimirova, D. (2019). Building sustainable value propositions for multiple stakeholders: A practical tool. *Journal of Business Models, 7*(1), 1–8 2019-01-01.

Wenner, F., & Thierstein, A. (2022). High speed rail as urban generator? An analysis of land use change around European stations. *European Planning Studies, 30*(2), 227–250. 10.1080/09654313.2021.1946485.

Wenner, F., (2020). Eurostar architecture: Comparing high-speed rail stations in Europe. 10.1007/978-3-030-23925-1_14.

Yin, Y. (2015). Evaluating compactness of cities by energy consumption efficiency. *Journal of the Eastern Asia Society for Transportation Studies, 9*, 713–723 2011.

Zemp, S. (2011). Classifying railway stations for strategic transport and land use planning: Context matters!. *Journal of Transport Geography, 19*(4).