RAIL4CITIES

Report on railway station model and SCP model

Deliverable 2.1

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Table of Contents

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List of Figures

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List of Abbreviations

Abbreviations / acronyms	Description
IAB	International Advisory Board
KPI	Key Performance Indicator
LL	Living Lab
SUMI	Sustainable Urban Mobility Indicators
TOD	Transit-Oriented Development
TUM	Technical University of Munich
UGI	Urban Green Infrastructure
UIC	International Union of Railways
UN SDGs	United Nations Sustainable Development Goals

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1 Executive summary

This report introduces a new model for current and future railway stations and demonstrates the changes necessary for them to play a significant role in a sustainable urban future. To date, there is a lack of a consistent concept to describe the potential of railway stations, making it challenging for all stakeholders involved to envision collaborative sustainable transition pathways. Consequently, the objective of this deliverable in the RAIL4CITIES project is to identify a common definition for European railway stations and to develop a model that emphasizes their distinctive role in urban landscapes, not merely as mobility nodes but as integral elements of urban life, impacting a diverse range of stakeholders.

This report proposes a new operational model for stations as Sustainable City Promoters, comprising three core components: (I) *appraisal, (II) fields of action,* and *(III) methodological toolkit*, discussed in detail across different chapters. The model is designed to be as universally applicable as possible, yet adaptable to local conditions, with the aim of facilitating the transition towards more sustainable and socially inclusive cities. For the first core component (I), we conducted a review of various approaches to station classification found in the literature and identified key performance indicators (KPIs) in order to assist in the appraisal of current and future railway stations. The *fields of action* (core component II) describe – as their name suggests – the various topics where action should be taken in order to utilize the stations' potential for sustainable urban transformation. These include aspects such as mobility, energy, and logistics. In order to guarantee the model's wide applicability, we furthermore introduce a *methodological toolkit* (core component III) to propose a methodology for bringing stakeholders together to envision and discuss the suitable way forward for every station and its context.

In addition to explaining the fundamental structure in core components, this report also concentrates on the detailed scientific process of model development, ranging from the literature review on which the *appraisal* is based to the series of workshops and their documentation that led to the development of the *fields of action* and *methodological toolkit*. The next steps of the RAIL4CITIES project will involve the testing of this draft model in several living labs and case studies situated across Europe. The data and experiences gathered in these living labs will be used to create the final version of the model during the final phase of the RAIL4CITIES project.

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2 Introduction

Stations hold a unique position in the urban landscape: They not only act as complex nodes of mobility providing points of access to trains and other modes of transportation, but also as public places that can be seen as integral elements of the city (Bertolini, 1998). This is the case especially in Europe, where stations are historically highly integrated into the respective urban systems. Stations are part of the social infrastructure of a city, rather than simply part of its mobility infrastructure (Banerjee, 2022). Therefore, they affect more stakeholders than just railway companies and travelers: businesses, consumers, other economic actors, communities, citizens – virtually everyone. The size of stations can range from large hubs serving over 1 million passengers per day to small stations serving only one main line with few passengers, but stations of all sizes have a decisive impact on their urban surroundings as places of everyday life (Pucci & Vecchio, 2019). Considering the urgently needed transformation of our urban structures towards more sustainable cities reaching the Sustainable Development Goals (SDGs), the potential of railway stations as key urban elements enabling cities to develop sustainably has so far only been marginally exploited (Spinosa, 2023). To date, there is no uniform approach to describing railway stations in Europe. Existing classifications cover partial aspects, such as the documentation of land-use patterns around stations (Wenner & Thierstein, 2022) to the assessment of their bike-train intermodality (Pazzini et al., 2023). This lack of a consistent concept makes it hard for policymakers, railway station operators, or civic initiatives to identify potentials for sustainable change in stations and explore the potential of stations as carriers of larger urban transformations.

Therefore, the project *"Railway stations for green and socially-inclusive cities (RAIL4CITIES)"*, which is supported by Europe's Rail and its members and funded by the European Union, aims at unifying different approaches to station classification and functions, in order to then derive a model useful for describing current stations as well as a sustainable future for them – and the transition pathways toward achieving this vision. Our aim is to describe an approach universal enough that it can be applied to stations of different sizes or urban surroundings, for example, while at the same time enabling sufficient latitude to accommodate specific local conditions or prevailing opportunities, thus guaranteeing opportunities to scale up the model to applicability across the EU.

In this report, a new operational model for stations as sustainable city promoters (SCP) is being introduced, and the theoretical considerations (chapter 3) that led to its development are described in detail. The model consists of three core components (Appraisal, Fields of action, Methodological toolkit) which are described in chapters 4, 5 and 6 of this report (cf. Figure 1). Using the method described in chapter 6, in chapter 7 we give an outlook on how this proposed model will later be corroborated with data from five living labs situated in France, Italy, Germany, Poland, Belgium, and three additional case studies in Portugal, testing specifically how railway stations can play a substantial role in sustainable urban development. While the process and results of the living labs are not part of this report, as they will be introduced at a later point in the research project, specific challenges and implications of the model application in the living labs are already addressed in chapter 7 of this report. The updated station model will integrate the data gathered in the living labs and will be documented together with an EU-wide methodology in the deliverable 4.1 "EU-wide SCP methodology", which is due by the end of the RAIL4CITIES project.

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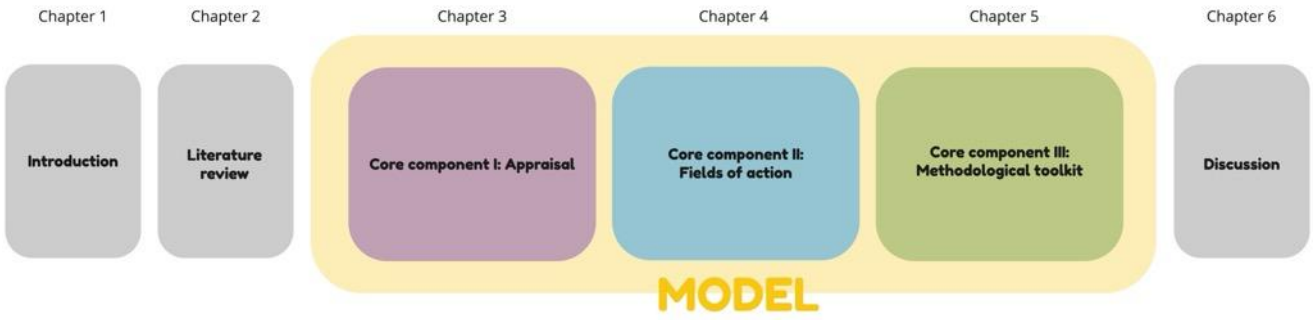

Figure 1. Structure of this report and model core components.

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3 Literature review

Up to date, there exists no generally accepted model to describe current and future railway stations that is both flexible enough to be adaptable to local specifics and at the same time universal enough to be useful in a vast range of contexts. As long as such a model doesn't exist, it remains hard to derive clear transition pathways to achieving a more sustainable railway station future.

One of the reasons such a generally accepted model doesn't exist yet is the complexity of describing and classifying railway stations – even if narrowing down on relatively simple indicators like passenger frequency to trace and categorize different stations, problems arise due to railway stations of a *similar* passenger frequency varying not only due to differing national policies and strategies, but also because of the many different roles of stations in the respective railway network, their infrastructural characteristics, and their spatial context. How does a railway station with more retail space score compared to one of a similar passenger frequency but with less retail space, for example – and on what scale? Correspondingly, railway stations of *different* passenger frequencies are even harder to compare. At the same time, some of the challenges different station types face apply rather universally, like for example the need for resilient infrastructure design in times of the climate catastrophe, thus making station classification a necessary, but – as already pointed out – also complex task. In order to be able to derive a first draft of a model for current and future stations, we conducted a literature analysis to identify current approaches to station classification in Europe.

The goal of this analysis is to provide an overview of the varying indicators used for describing European stations and their potential sustainability transformation pathways. This in turn allows for the identification of recurring fields of action which are relevant for different stations and which thus should be part of our model. Additionally, the station classification helps identify various transformative methods which are necessary to make the model operational and applicable in a wide range of contexts while malleable enough to also be applicable locally. Thus, the literature analysis serves as a basis for extracting relevant indicators to develop suitable KPIs for railway station appraisal (core component I). Additionally, it contributes to the identification of fields of action (core component II), and the methodological toolkit for the model application (core component III).

While our focus lies primarily on an academic literature review due to its relevance to the station model development, we also included an overview of the intermediate results of the UIC Station Categorization Project in order to gain insights on the station classification systems currently in use by the railway industry. The following chapters contain a brief digressive summary of the UIC project results (3.1), the theoretical background and methods of the literature review (3.2), as well as its results (3.3), thus providing an overview of the different station classification systems discussed in academia and industry within the European context.

3.1 Digression: UIC SMGG Station Categorization Project

Parallel to the first phase of the RAIL4CITIES Project, the consortium partner UIC has already been working on a station categorization benchmarking project which, among others, provides an overview and comparison of the different systems of station classification developed by railway companies around the world. In this report, we used the raw data produced by the UIC project up to October 2023 and focused on the companies based in Europe in order to compare the railways' station categorization

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methods with the results of the academic literature review described in more detail in the next chapter.

Among the railway industry station classification methods, the most important criteria seem to be the passenger footfall and number of trains passing through the station in a specific timeframe, as well as station characteristics, assets, and services. In some systems, the location of the station in the network plays a role (e.g. French railways, also in the form of long-distance train stops by the German railways), reminding of the “Node” aspect in the Node-Place model by Bertolini (1999, cf. next chapter). Further criteria include intermodality aspects (e.g. Portuguese railways, Spanish railways, Italian railways), touristic aspects (Portuguese railways), and station revenue (British railways). Loosely corresponding to the “Place” aspect of the Node-Place model, factors such as resident vicinity (German railways), characteristics of the territorial context (such as population, employment factors, and points of interest by the Italian railways) and the general role of the station in the urban context and citizen life (French railways) are included in the classification methods. Most important among the purposes of the classification systems seem to be the consolidation of the business model, the prioritization and acquisition of investments, the definition and standardization of facility requirements, services and equipment, as well as the charging model, since train operators differ from station operators. Additionally, the enhancement of the customer experience seems to play a role as well, be it directly or indirectly.

Newer classification systems that are either in development (e.g. by Spanish railways) or already in use (e.g. Italian railways), seem to be focusing (apart from transport characteristics) on the relationship with other modes of transport and businesses in the city. These classifications include aspects of multimodality, as well as urban and commercial characteristics of the station and its context, often considering the station as a “product for the city”, for rail and non-rail purposes. Acknowledging the importance of stakeholder cooperation, the new classification system by the Italian railways aims to improve stakeholder engagement, spanning from central government, local authorities, commercial parties, to citizen associations. Furthermore, it introduces the TAG system (containing different “labels” for each station), which for the time being is unique among the classification methods, and allows for clustering of stations which belong to different categories, according to specific characteristics of themselves or their context.

Last but not least, it is important to note that additional classification systems exist in specific contexts, such as the cleaning and security categorization of the Danish railways within the framework of the "safe station initiative", highlighting the influence and interest of politics to ensure a good perception of stations.

3.2 Theoretical background and methods of literature review

Contrary to the railway industry classifications, approaches in literature are seldom applied (with very few exceptions, such as the utilization of the Node-Place Model, Bertolini, 1999, by the Dutch Administration and Railways, according to Peek et al., 2006). There do not seem to be any station classifications originating from e.g. governmental offices dealing with spatial development (Zemp et al., 2011). This is striking, given the potential usefulness of such more comprehensive classification approaches.

The tool of station classification per se can contribute in various ways to strategic spatial planning and decision-making. For example, Pucci and Vecchio (2019) mention that such a classification of stations could be a useful tool for the construction of scenarios that reorganize land-use forecasts and improve

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both the accessibility and quality of the services in stations, in order to widen the catchment areas of each station. Zemp et al. (2011) mention the potential of classifications to identify comparable stations with respect to certain questions: “For the infrastructure companies this reduces management complexity by enabling the application of standards in operations and development, securing consistency of actions across large portfolios and geographic regions. Similarly, for the other actors, such as local spatial planning bodies, it enables the identification of sites and actors with comparable challenges or experiences” (Zemp et al., 2011, S. 670).

Furthermore, the same authors mention the capacity of classifications to enable comparisons and performance assessments within the station classes, identifying successful benchmarks or highlighting needs for action. This particular potential of classifications is used within the framework of this study in order to develop KPIs. Last but not least, Zemp et al. (2011) mention the potential of classifications to support the identification of general development potentials and necessary future adaptations of whole station classes. However, as we will see, different authors use the tool of station classification in order to fulfill different, sometimes very specific, goals.

The methodology of this literature review consists of five steps (Figure 2). First of all, an identification of relevant publications in the databases of *Scopus* and *Web of Science* took place. We searched for scholarly publications that included the following keywords:

- railway AND station AND classification (N = 435)
- railway AND station AND categorization/categorization (N = 18)
- railway AND station AND classify/classifying (N = 241)
- railway AND station AND grading (N = 105)
  (All N numbers *prior* to deleting duplicates)

After identifying the relevant results, we limited the results to English and German publications and deleted duplicates. The remaining publications were screened on the basis of their abstract and title. Through this process, we were able to identify 496 relevant publications. Since this study aims at producing knowledge about the European context, only results from the European context were selected for further analysis. Apart from the location and context, further criteria for the selection was the presence of a railway station classification and/or rating system resulting in a hierarchical categorization of stations. The number of stations classified was not considered a criterion as long as it was >1. The same applied to the type of station and the examined catchment areas.

The preparation of the third step included retrieving the selected publications through online resources which were either Open Access or accessible through the TUM University Library licenses. Publications that could not be retrieved this way were ordered through interlibrary loan (“Fernleihe”) from different German universities, or by directly contacting the authors. Publications that were not accessible through these methods were excluded from further analysis. The available full-access articles (N = 13) were analyzed in order to assess their eligibility and relevance to the topic. This way, further sources mentioned in these publications were identified (snowballing; N = 11), retrieved, and analyzed as well. The last step involved the extraction of relevant information from the analyzed publications and their systematization in a way that they can contribute to the further development of the project. This step was carried out for 24 eligible publications. The methodological approach for the literature review is summarized in Figure 2.

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Figure 2. Methodological approach for literature review.

3.3 Results of literature review

The typical structure of the screened papers consists of the development of a classification methodology and its application in a case study area. The classification is either based on several references (e.g. Eichhorn et al., 2021), by developing an own classification system (e.g. Kruszyna & Makuch, 2023), or by modifying an existing one (e.g. Vale, 2015). Some papers present a thorough literature overview (e.g. Pucci & Vecchio, 2019) and most publications apply the chosen classification method to a case study. The case studies where the systems are tested differ in their scale and nature. One can further observe that similar methods are being applied to different sample scales and railway types (e.g., regional network, Caset et al., 2018, or urban network, Vale, 2015). Furthermore, it should not be forgotten that the availability of data sources has a significant influence on the aspects included in each study.

The introduction of the Node-Place Model by Bertolini (Bertolini, 1999) seems to have influenced a large number of classification studies, even though since its elaboration in the 1990s, it has been interpreted and used in many different ways, and adjustments have been advocated and implemented. Thus, many authors, following Bertolini's approach, use indicators that address both the role of the station in the transport network ("Node"), as well as the characteristics of the station's spatial context ("Place"), but there are also a number of enhancements or variations of the Node-Place model being proposed, for instance by adding factors or focusing on a specific topic, such as the addition of indicators relevant to sustainability judgments (Reusser et al., 2008). Further studies have adapted the model to national conditions due to the different transport behavior of passengers in the local context (Ivan et al., 2012), or have used the Node-Place Model as a conceptual basis while using own indexes as Node and Place indicators (Papa et al., 2013).

As in the Node-Place Model (Bertolini, 1999), a common aim among these publications seems to be the investigation of the relation between land use and public transport, and the possible resulting (transit-oriented) development. In this way, these studies bear the potential to assist strategic urban and transport planning processes on a regional or even on the urban design scale.

Contrasting the duality of the Node-Place Model, different classifications arise when the goal is primarily to support station managers or to define the necessary services provided at the station. Though such studies are not only commissioned by the railway industry, they are based mostly on the characteristics of the station as a "Node" (varying from transportation characteristics to station usage), while only taking basic factors of the context such as the size of the nearest settlement into account (Antonowicz & Moś, 2018).

In contrast to studies concentrating on the station itself, there are publications that mostly ignore the station characteristics, and choose to rather analyze their surrounding areas. For example, Zemp et al. argue that "a classification system for strategic planning should focus on the demands and conditions of the site within which the railway station must function, i.e. system context" (Zemp et al., 2011, p. 670). The goals of such studies are mostly to support strategic transport and land use planning.

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Though most station classifications are limited to a certain national or regional context, there are notable exceptions that show a clear international orientation. For example, Wenner and Thierstein (2021) analyzed the land use change around 232 stations that have been constructed in Europe since 1981 or are currently under construction. Here, among goals such as the analysis of land use change, the authors aim to create comparisons between different contexts in the EU, thus adding an additional layer of complexity to the studies.

Setting themselves apart from the rest, several classification methodologies concentrate on a rather specific topic, such as the possibility of stations acting as a core of a 15-minute neighborhood (Borghetti et al., 2021). These classifications tend to use more specific criteria than the rest, adapted to the according topic. In the example of Borghetti et al. (2021), the criteria mostly depict the presence, number, and distance from various city functions to the railway station. Here, the purpose of each study is different, since it is closely related to the specific topics that are included in the classification factors.

Finally, it is important to note that the topic of catchment area definition bears differences in the perception of the spatial contexts of a station in the analyzed classification methodologies. For example, Eichhorn et al. (2021) argue for 15-minute walking isochrones, whereas Soczówka and Żochowska (2022) suggest an 800m simplified distance without considering road and street network. Caset et al. (2018) have recognized this disparity and have explored the influence of different catchment size areas on the outcome of their analyses, by comparing four different catchment area sizes (1,200m, 700m, 800m, 3,000m).

Summarizing the characteristics of the aforementioned studies, one can highlight several factors that are relevant and that differ significantly in the various classification systems:

- The theoretical framework (e.g. the use of the Node-Place Model as a basis or not)
- The goals and purposes of the classification
- The balance (in importance, or number) between aspects regarding the station and aspects regarding the surrounding context
- The case study scale and number of stations investigated
- The railway type or combination (HSR/Regional/Urban/Suburban)
- The quantitative method of classifying and clustering (principal component analysis/point systems etc.)
- The different definitions of catchment areas
- The number and type of groups/clusters (if any)

Reflecting on the results of the station classification, it becomes clear that the transformation of stations into intermodal mobility hubs and vital elements of the urban realm is reflected in the development of classification methods. While the railway industry is slowly shifting its focus from mere operational aspects of station infrastructure towards methods which address the interplay of stations and their surroundings, scholars mostly choose to classify stations in ways that include the station context, thus advocating for an integrative approach of the role of the station both as a node in the transport network as well as a place in the urban landscape.

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However, this trend highlights the increased complexity of classifying stations as a way of assisting strategic sustainable development. The numerous criteria and characteristics, while underlining crucial relations of stations to their context, make it hard to develop clear generic strategic guidelines for universally defined station types.

Reflecting on these results, we chose to develop a model which has the capacity to assist the development of strategies for different station types, without the constraints of predefined rigid categories. The next chapters of this report describe the three core components of this model (chapter 4: appraisal, chapter 5: fields of action, chapter 6: methodological toolkit), which are not specific to any station category or class. However, the capacity of the model to address different situations via context-specific indicators (appraisal) and themes relevant to the station context (fields of action) brings about the necessity for a method of identifying suitable transformation pathways for each station. In order to assist this process, the third core component (methodological toolkit) concentrates on a methodology for the development of specific strategies for each station case study.

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4 Core component I: Appraisal

The definition of a model for the railway station of the future should not only consist of the description of a common objective and target vision. On the contrary, it should furthermore include indicators that assist the assessment of the current station situation as well as the progress towards the objectives defined in the model.

Thus, the first core component of the station model focuses on the development of KPIs which will allow the appraisal of the station situation both in the present as well as in the future, e.g. during transformation processes. The literature review on station classification methods across the EU which is described in the previous chapter has been used to extract indicators which were converted into suitable KPIs for the railway station appraisal. These KPIs, extracted from the literature, were then discussed and refined in internal consortium workshops. Thus, while the literature review served as the main theoretical basis for the KPIs, the workshops were used to validate and discuss the various KPI suggestions. The process of the development of these key performance indicators (KPIs) is described in chapter 4.1, while selected results can be found in chapter 4.2.

4.1 Theoretical background and methods of KPI development

RAIL4CITIES as a project is following the common path towards sustainable development at European and global level, which is (among others) embodied by the United Nations Sustainable Development Goals (SDGs; for example: goal #11 sustainable cities and communities; goal #7 affordable and clean energy, goal #3 good health and well-being, goal #5 gender equality; goal #13 climate action), the Sustainable Urban Mobility Indicators (SUMI) and the Urban Agenda of the European Union (so-called “Pact of Amsterdam”, European Union, 2016). These documents acted as a basis for the development of the KPIs; the latter two were added in the process in order to specify the SDGs of the United Nations within the context of mobility and urban development.

The development of KPIs as part of the station model definition was the result of a multi-layered methodological process consisting of a literature analysis on station classification (c.f. chapter 3 of this report) and various workshop formats. Through screening the Pact of Amsterdam (European Union, 2016), the SUMI, and the UN SDGs as a theoretical basis, relevant generic topics for the KPIs have been selected. These topics were analyzed and expanded into specific objectives for the RAIL4CITIES project. These objectives are related to various SDG targets. For these objectives, first, relevant KPIs were formulated during two different workshops with the RAIL4CITIES consortium (30.08.2023, 27.09.2023). Through the literature research carried out by TUM, the proposed KPIs were further specified and additional KPIs were added. Furthermore, the format of the IAB international experts’ workshops, where IAB experts provided additional expertise in numerous different disciplines was used to add further KPIs to the list. According to their nature, KPIs were tagged either as quantitative or as qualitative. Finally, the KPIs and their categories have been consolidated and assigned to the SCP Model fields of action (cf. chapter 5) which have been developed parallel to the KPIs. Figure 3 illustrates the methodological approach.

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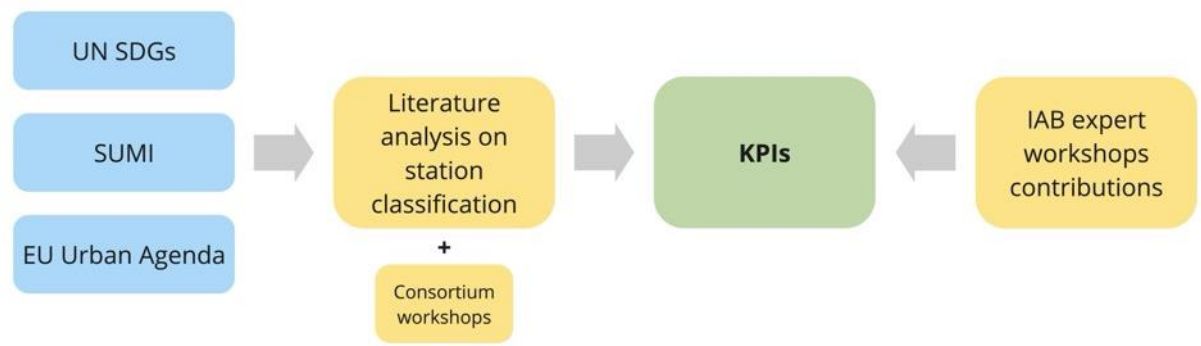

Figure 3. Methodological approach to define KPIs.

4.2 Results of KPI development

Reflecting on the results of the literature review, it becomes clear that the used KPIs depend on the study goals, which in the case of the railway industry are usually oriented on the topic of transport, whereas academic publications usually (also) utilize data of the surrounding area and context. The different expert opinions represented in our KPI workshops by the various consortium members also highlighted the need for interdisciplinarity in the KPIs. This complexity is further highlighted in the literature by scholars, who emphasize the fact that stations, being public spaces of key modal interchange, "should acknowledge their multifunctional potential, and embrace the complex design and management task, comparable to that of designing a city centre to meet the needs of a wide range of users and offer good access to sustainable transport modes" (Otsuka & Reeve, 2023, S. 34).

Therefore, we included various indicators that do not only concentrate on the station itself but also on the station's impact on urban transformation and citizen life. Due to their nature, some of these indicators are not directly quantifiable and have a rather qualitative character. The need for the combination of quantitative and qualitative indicators has been also raised in existing literature, such as in Otsuka & Reeve, 2023.

Following, we provide exemplary KPIs for various topics relevant to the RAIL4CITIES project. The topics correspond to the station model fields of action, whose development and description can be found in chapter 5 of this report.

On the topic of **mobility**:

- Degree of rail integration with active mobility and on-road mobility services (e.g. MaaS integration, ticketing).
- Presence and quality of active mobility infrastructure for access to the station, walkability (e.g. bike lanes, footpaths).
- Frequency in regional and long-distance traffic and transfer potential to local transport.

On the topic of **urban development/TOD**:

- Diversity of usage of/actions in the station and surrounding public spaces, degree of mixed use of surrounding urban structures.
- Building density/number of inhabitants of the area around the station.

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- Space allocated to inactive public transport directly in front of the station, space efficiency in the areas surrounding the stations.

On the topic of **circular economy**:

- Reuse rate of materials and resources within station infrastructure projects to minimize resource consumption.
- Amount of food waste in shops and restaurants inside train stations.
- Water and water usage (and reuse) in waste (I.e., water that goes out should be cleaner than the one that goes in).

On the topic of **energy**:

- Amount of energy which is necessary for operating (e.g. cooling/heating etc.) the station, percentage coming from sustainable sources.
- Amount of energy produced in a sustainable way within the station itself (e.g. train regenerative braking for energy efficiency), percentage of energy sufficiency.
- Amount of grey energy for the production of materials used for station renovation/remodeling.

On the topic of **logistics**:

- Reduction in emissions and traffic congestion because of innovative last-mile delivery through railway stations (vs. traditional delivery).
- Improvement of reliability, delivery time, and customer satisfaction.
- Impact of logistics on regular station operation and financial revenue.

On the topics of **resilience and green-blue infrastructure**:

- Amount of urban green-blue infrastructure projects realized/planned within the framework of the railway station redevelopment and the surrounding urban structure transformation.
- Share of unsealed areas in the public spaces surrounding the stations.
- Number of rail service interruptions due to natural events (e.g. flooding, heatwaves, earthquakes)

On the topic of **social-inclusive services**:

- Existence/regular operation of participative processes for the design of the station and the surrounding spaces, level of citizen engagement.
- Availability of municipal social services within 15 minute walking distance from the station.
- Diversity of users using the station and surrounding public spaces, the feeling of safety and security for all user groups.

It must be noted that since the methodology of the model application in the various living labs (cf. chapter 6) includes the development of further KPIs through participative workshops, there is a possibility for the local stakeholders suggesting additional indicators which suit their specific needs and are adjusted to the local context. This process fosters the development of common, innovative KPIs that are directly linked to the conditions of the stations, thus providing a solid and realistic pathway for the assessment of sustainable development of stations.

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5 Core component II: Fields of action

The second core component of the station model focuses on the different fields of action which are relevant to the transformation of railway stations into sustainable city promoters. Based on the hypothesis of Bertolini & Spit (1998) that the development of railway stations is such a difficult task because of divergent perceptions and the suggestion of the same authors that it "should be viewed from several perspectives at the same time" (Bertolini & Spit, 1998, S. 4), we chose the format of expert workshops assisted by literature analysis as most important components for developing and choosing these fields of action. We are aware that there are different ways to address this topic apart from the workshop and literature formats, such as case study research and comparison. However, we chose to start with a robust workshop methodology including the various stakeholders, while gaining theoretical background through literature, aiming to employ further methods in future research projects and compare the according results.

5.1 Theoretical background and methods of fields of action development

In order to acquire knowledge about the various topics which are relevant to future railway station development, we conducted two different workshop rounds. While setting up the methodology of the workshops, we asked the railway partners in the consortium to provide us with information about basic aspects of station management by answering a questionnaire. Thus, we were able to better prepare the topics of discussion for the workshops. Among the questions asked were for example: "How are the public spaces around stations managed? How do you currently collaborate with the city municipality to manage the public spaces around the stations?", "How are the commercial areas within the train station managed? Are private real estate companies granted administrative concessions for these spaces, or do you manage them by yourself? In either scenario, who is responsible for determining the types of businesses that can operate within the station?".

The first workshop round was of an analytical nature based on the Cambridge Value Creation Model (Vladimirova, 2019) (Bocken et al., 2013) and consisted of three workshops that took place in October 2023, addressing different stakeholder groups according to their field of expertise and current activities (railways and industry, academia and experts, cities and urban governance). The Cambridge model's structure aims to identify uncaptured value (e.g. yet unidentified potentials) by aligning the interests and needs of different stakeholder groups and exploring their differences. Thus, the invited experts (most members of the IAB and the members RAIL4CITIES project consortium) were asked to analytically discuss the current situation of railway stations within the framework of various relevant topics such as intermodal mobility at the stations, the stations' spaces and services and the potentials of transit-oriented development, for example. The experts' background included different relevant disciplines, such as urban governance, urban development, urban mobility, station architecture and design, station management and operation, rail systems engineering, transit-oriented development, placemaking and urban climate adaptation.

By combining the contributions of the first workshop round with the already developed KPIs, we were able to define the fields of action of a first draft of the station model and develop a method for applying the model in the living labs (the third core component of the station model, described in detail in chapter 6). This method consisted of a workshop structure which is thematically focusing on the model

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fields of action and is intended to be used by local stakeholders in the living labs (including e.g. railway companies and urban governance bodies) in order to elaborate the applicability of the model in each specific context.

The second round of digital workshops took place in November 2023 and had two main objectives. On the one hand, the workshops aimed to test the proposed methodology for the model application in the living labs (described in chapter 6), by using the various experts of the consortium and 24 selected members of the IAB with different expertise backgrounds as representatives of the local stakeholder groups. On the other hand, it aimed at validating each of the model fields of action.

5.2 Results of fields of action development

By combining all knowledge acquired through the workshops and literature research, we propose the following seven fields of action as the base of the station model which describe the diversity of roles railway stations will have to assume in the near future.

- Station as a hub of intermodal mobility
- Station integration into the city (e.g. how to develop surrounding urban areas, TOD)
- Station as a circular economy hub (e.g. how to promote recycling and reusing of materials)
- Station as energy hub (e.g. how to produce energy locally)
- Station as a logistics hub (e.g. last mile delivery)
- Resilience and green/blue infrastructure (UGI) - station as a "greening engine" for the city
- Station as a hub of socially-inclusive services for citizens (e.g. proximity, safe and democratic spaces of exchange)

Within the next chapters, the fields of action are described in detail.

5.2.1 Station as a hub of intermodal mobility

In order for public transport to present a viable and more sustainable alternative to private motorized mobility, railway stations need to become hubs of intermodal mobility, connecting various mobility services, from high-speed railway traffic to public transport and shared urban mobility services, such as bicycles and e-scooters. The degree of functional and spatial seamlessness of transition between these services is of great importance. On the functional side, this goal can be achieved through multimodal ticketing options and further (digital) integration of different mobility services. On the other hand, an efficient arrangement of curb spaces which provides spatial proximity between the various forms of mobility (public transport, shared transport, railway transport) reduces the time spend during transfer between different means of transport and reduces the need for private motorized mobility.

However, interventions at the railway station itself are not enough to transform it into a multimodal mobility hub. The connection of the station to the broader catchment area and surrounding urban centralities remains of utmost importance, since it provides potential users the possibility to reach the station by using means of active mobility and thus avoiding car use. The transformation of the streetscape to a walkable urban landscape, providing bike lanes and bike parking spaces, and the

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efficient planning of public transport is necessary in order to improve the accessibility of the station. A reduction in car use as a means to get to the railway station can in turn free valuable spatial resources near the station which were previously used for car parking, thus enabling their conversion to more sustainable land use, such as green-blue infrastructure and public spaces.

On the topic of intermodal mobility, challenges are present through the usually very fragmented governance of railway stations and their surroundings, thus challenging the capability for investments supporting large transitions. The evolution of railway stations to intermodal hubs requires the cooperation of various stakeholders in functional (e.g. data sharing, ticketing, timetables) and spatial aspects. Furthermore, in some contexts, the ownership structure in and around the station can be a challenging factor for common investments. New modes of stakeholder management (e.g. between railway, public transport company, and municipality) are needed, thus calling for new, overarching governance structures for decisions on investments and operation, addressing different stakeholders and enabling them to work together. Last but not least, the importance of evolutive changes (in contrary to disruptive changes) regarding the transition from cars to bikes and micro-mobility should be emphasized and supported by suitable incentives (e.g. full-journey ticket, congestion fees, etc.).

5.2.2 Station integration into the city (e.g. how to develop surrounding urban areas, TOD)

The topic of mobility spaces is closely related to the station integration in the city and transit-oriented urban development (TOD). Especially, the effects of high-speed rail have been mentioned to influence the urban fabric in various ways. These can be functional effects (e.g. attraction of knowledge-intensive firms due to an increase in accessibility), spatial effects (e.g. changes in urban design and architecture), or temporal effects. These effects can happen on various scales, for example in the immediate vicinity of the station, in the whole cityscape, or in the functional region.

The solutions and strategies for TOD highly differ depending on the local and national context. Countries such as Germany, Netherlands, and Switzerland have integrated high-speed railway transport into the existing rail network, meaning that old stations have kept their importance, leading to intensive synergies with the development of existing urban fabrics. In these cases, the efficient use of space, the role of car mobility, effective curb management, and the transformation of the surroundings due to high accessibility become important topics which have to be addressed. The presence of an accessibility point such as a railway station leads to a spatial and functional transformation of the urban fabric, which has to be strategically addressed by urban governance bodies, in order to avoid functional monocultures. A further challenge is the duality of the front-side and back-side of the station, meaning that the station often features a representative front side, coupled with quality public spaces, while all unwanted functions and infrastructures are concentrated on the back-side. Experts emphasized the need to design stations which are open to both sides in a similar way.

Contrary to the integration of high-speed rail in the existing network, a number of countries (e.g. France) have been constructing railway stations outside of cities (sometimes even serving two different cities at the same time), an arrangement whose success often depends on the connection to the existing urban centralities and the development of high-quality new urban centers around the stations, a process which often takes a lot of time. In this case, challenges appear due to the long development duration of the project, the possible monofunctional urban development around the station, as well as the difficulty of balancing multiple objectives (e.g. dense urban development and good access to the railway station). An adaptable planning process, taking into account new trends/conditions, and a

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functioning connection to existing urban centers are identified as possible solutions for this type of stations. A further challenge is the current conception of TOD as a growth-only principle: New urban development happens where stations are placed, but not vice versa. Furthermore, the politically controversial topic of negative urban development (e.g. urban shrinkage) and the possible reduction of railway services is hardly discussed.

In both cases of urban transformation, governance structures can pose issues. Successful TOD requires the productive cooperation of railway companies with various entities of urban governance on regional and local levels, as well as with private stakeholders (e.g. investors, landowners, local community), and the definition of common goals. Furthermore, the top-down decision-making structures which often characterize railway infrastructure planning can be problematic, since they do not always consider local conditions and interests.

5.2.3 Station as a circular economy hub (e.g. how to promote recycling and reusing of materials)

Circularity is an important topic for railway stations on the way to a more sustainable future. However, it is of utmost importance for all stakeholders involved to grasp that for stations to become real hubs for circularity, they need to address more than just waste management – in fact, a more holistic view focussing on regenerative design is necessary to achieve a Net Positive, meaning train stations contribute more to their surroundings than they take from them (Cole & Fedoruk, 2015).

This requires acknowledging the complex stakeholder structure at play and the location-specificity of a lot of the possible solutions, meaning that while there is a common goal to, for example, achieve the transition to energy independency (whether totally or partially), the pathways to achieve this transition can be very specific to each country or even train station.

To overcome such boundaries, it is necessary to have conversations with all stakeholders involved (that is, not only the city or the railway station, but also hospitals, shops or the community in close vicinity that are embedded into the system design of the station, but also with experts focussing on waste management, for example) about the topic of circularity and to develop highly implementable, replicable and universal methods that can be tailored to local needs and highlight individual potentials instead of global archetypes or one-size-fits-all-approaches. Economic benefits of using circular approaches should be highlighted and, to further maximize the economic success of going circular, innovations that are already available should be used. A full audit is advisable to gather data on waste management, energy, water, soil, biodiversity, people, and to, for example, identify all types of waste accruing in and around a station. As soon as all relevant material flows are identified, then one can start looking for more sustainable alternatives and substitutes and develop concepts for mining high-value materials (= urban mining). At the same time, it has to be acknowledged that trying to, for example, increase biodiversity or to prevent soil pollution by planting, rewilding, bringing animals to the station or using regenerative farming on a mini-scale around the station, is a marathon, not a sprint, and that different groups of stakeholders might have different needs and ideas to achieve well-being for all. Thus, open-mindedness for solutions off the beaten track, ranging from hyper-specific local approaches to more global goals, is needed.

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5.2.4 Station as an energy hub (e.g. how to produce energy locally)

Stations should aim to become energy hubs, where energy is locally generated at the station with renewables and used to power not only the station building, but also green mobility services and infrastructure available at the station (e-bikes, car sharing, e-scooters, both private and sharing services). The main objective is to have a long-term structural change in energy systems with a shift to renewable and efficient energy, including better energy management at the station level, allowing for energy flexibility and resilience of Electrical Smart Grids, and increasing the local production of renewable energy. In the workshop, three important measures were mentioned which would allow a station to become an energy hub, namely feeding energy directly into the local rail grid, increasing the share of renewable energy in the total consumption with innovative solutions, and revising the amount of grey energy used in stations.

With regard to *feeding energy directly into the local rail grid*, the workshop participants mentioned several international examples and their challenges and boundaries, like a pilot in Norway where the energy feeds into the rail grid, and it is transformed to the correct voltage. In general, this solution has the following implementation limitations on a technical level i.e. regarding the compatibility of the energy/frequency produced with different trains as well as on a regulatory level, specifically regarding standardization, and on an economic level regarding the lack of interest in investing in innovations with a low return of cost invested, like for example for photovoltaic benches in Italy where people can sit comfortably waiting for their train while carrying out other activities such as charging their phones. As another example, geothermal heating for platforms was mentioned. The challenge here is that it is costly and hard to implement in existing train stations. In order to find solutions to the challenges posed by implementing measures like the ones mentioned as examples, the importance of feeding the energy directly into the rail energy grid was discussed. However, the importance of the placement of these strategies in the political agenda regarding regulation to promote sustainable energy was highlighted as well as a necessity to make the realization of these solutions feasible (e.g. through subsidizing the implementation of renewable energy solutions)

With regard to *increasing the share of renewable energy in the total consumption using innovative solutions*, the participants mentioned different strategies such as the installation of passive solutions like natural ventilation, more efficient insulation materials and shading systems. However, the challenge of existing buildings being expensive to maintain and to modify was pointed out as these buildings may be under monument protection. Another example of a solution mentioned was implementing solar panels in the parking lots of big stations. From an economic, cost-benefits-assessment point of view, the challenges and boundaries for this to happen include the necessity to produce a lot of energy to surpass the cost of the project; in addition, the time to complete the installation and the activation in terms of organizations licenses must be considered from a bureaucratic point of view. Here, the importance of subsidies for renovating historical buildings and change regulation to be more flexible with buildings that serve a public function as well as help when dealing with bureaucracy should be pointed out.

Regarding the *revision of the amount of grey energy* used in stations to produce materials used for station renovation/remodelling, there is a need to certify buildings according to standards like the BREEM Standard, German LEAD standard, or Lifecycle assessment EPD, and the importance of the calculation of energy used to produce the material. Such standards should incorporate aspects like sustainability (for example, a detailed overview of the emission production value to know the quantity

of usage of the energy in the entire process) and ethical labor conditions with incentives like tax deductions to adhere to these standards.

5.2.5 Station as a logistics hub (e.g. last mile delivery)

Railway stations bear great potential to acquire the function of an urban logistic hub. This is due to their central location in the urban fabric, as well as their excellent connection to the rail transportation and freight network. In order for railway stations to be part of innovative last-mile delivery services, two topics have to be addressed. On the one hand, the railway has to become (again) a way of transporting consumer goods to stations, such as parcels and private packages. On the other hand, the station itself should become a place, where these parcels are picked up and transferred to their final destination through sustainable means of mobility, such as bicycles or e-vans.

The challenges and boundaries for this to happen are many, starting with the spatial resources in railway stations, which have to be adjusted in order to allow the logistics function. Furthermore, cooperation with rail providers and postal services is necessary in order to make the transport of parcels possible on trains. The area around the station has to be optimized for last-mile delivery, for example using dedicated lanes for cargo bikes. This calls for dynamic and strict curb management, possibly with pickup and drop-off during different times of the day. The station design has to be adjusted and conceived in a flexible way, in order to allow for the addition of logistics functions.

One of the most important solutions according to the results of the workshops, which would allow the integration of logistics functions into stations, is the tight integration of the logistics function into the station business model. Rather than being seen as a foreign add-on, logistics should be conceived as a part of the station business model, bringing revenue and being essential to the station's functioning, just as other commercial uses. This means that according to the station type, different logistic functions have to be conceived, from simple lockers to parcel distribution hubs. Furthermore, thinking more broadly about station design, one should think of integrating logistics functions near the railway station, for example in former car parking facilities, thus avoiding conflicts with existing commercial uses.

5.2.6 Resilience and urban green-blue infrastructure (UGI) - station as a "greening engine" for the city

Though the topics of *resilience* and *urban green-blue infrastructure* (UGI) are not the same, they can present some synergies when it comes to the transformation of railway stations. The main goal of a resilient station is to remain functional in every condition, even when it comes to natural phenomena such as earthquakes, floods, and heatwaves. First and foremost a station should remain functional for the train service (even if the station itself is not accessible for passengers), in order to avoid causing interruptions in the transport network. This can be achieved by adopting suitable design and construction standards in new stations or retrofitting existing ones with the appropriate infrastructure (e.g. in case of flooding: temporary barriers). Secondly, a resilient station should remain accessible for passengers, even in difficult natural conditions. In this case, different solutions (such as overpasses in the case of flooding) are necessary in order to maintain the flow of passengers through the urban fabric to the station. Since they are not limited to the station area, most of these solutions can be effective only if there is fruitful cooperation between the station management and the municipal authorities. In both cases, where resilience is needed, nature-based solutions such as green facades and roofs (against heatwaves) or natural water retention areas (against flooding) can be adopted in order to mitigate the natural risks and at the same time provide ecosystem services.

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However, such green-blue infrastructure is of limited use if implemented only in and around the station. Here, a more complex transformation strategy is needed, where the integration of UGI can take place on a bigger scale and through various projects. This could be achieved by conceiving and implementing bigger plans that contain the (transit-oriented) redevelopment of a whole station area and/or its connection to the surrounding centralities. Such masterplans present a variety of chances for integrating urban green-blue infrastructure (e.g. through the transformation of the streetscape/ public spaces, new building facades, and sustainable land use), yet require close cooperation and funding by multiple entities, such as the municipal authorities, railway companies, and private investors. Furthermore, such projects require a high degree of expertise in urban planning and urban ecology, thus calling for cooperation with appropriate research institutions.

Through appropriate planning, the adoption of transit-oriented urban development principles can support the development of UGI in different ways. Being less dependent on cars, neighborhoods with high accessibility can allocate spatial resources such as parking spaces and streets for the development of ecological infrastructure, while also increasing the walkability of public space. One should not forget that the role of ecology in TOD has been present since its definition by Peter Calthorpe (1993). Furthermore, possible synergies between green urbanism and TOD have also been explored by scholars, such as Cervero and Sullivan (2011).

5.2.7 Station as a hub of socially inclusive services for citizens (e.g. proximity, safe and democratic spaces of exchange)

Discussing the potential of railway stations as hubs of socially inclusive services for citizens, two important thematics should be highlighted. The first one is addressing the station design processes. Usually, railway station design occurs within the confines of local government offices. However, to ensure a holistic understanding of community needs, it is essential to extend the conversation directly to the citizens who utilize these spaces. This requires a paradigm shift toward inclusive decision-making processes that involve residents, local communities, users of the space, travelers and commuters, businesses, employees of the station and other stakeholders. Involving citizens in decision-making ensures that spaces are crafted with a profound understanding of community identity, fostering ownership beyond economic considerations. Additionally, defining stakeholders beyond immediate economic concerns would ensure spaces are valued for their inherent contributions to the city, not solely for profit.

Addressing the funding challenges for social infrastructure at railway stations demands a nuanced strategy aligning economic interests with community well-being. Innovative solutions are needed to incentivize railway companies and city governments by showcasing the economic benefits arising from increased passenger numbers and station usage. Economic incentives for railway companies, such as emphasizing the long-term advantages of socially inclusive stations, can appeal to their profit motives. Demonstrating social infrastructure planning as a lucrative business opportunity through case studies and aligning social goals with city interests further underscores the holistic advantages of such investments.

Leveraging the Scandinavian model as a reference point emphasizes the serious consideration of environmental and social factors in successful urban development. Positioning social infrastructure as pivotal in meeting global targets resonates with city decision-makers. Lastly, highlighting the role of social infrastructure in community empowerment and providing quantifiable metrics demonstrating improvements in passenger satisfaction and economic externalities would serve as a persuasive tool for convincing both railway companies and city officials of the tangible benefits. In conclusion,

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catalyzing change requires a strategic approach that balances economic interests with broader visions, showcasing benefits, aligning goals, drawing inspiration from successful models, emphasizing community empowerment, and providing quantifiable metrics. This approach could convince stakeholders of the crucial role social infrastructure plays in creating sustainable and thriving urban spaces.

The second thematic addresses social quality in railway station design by emphasizing group interactions, assessing the duration people can stay in a space, emphasizing lingering without the necessity of payment, focusing on people gathering in groups rather than just moving from point A to B, and having a balanced demographic inclusivity. The topics should be addressed both inside and outside the station. Inside, by developing a social business case within the station premises, demonstrating the economic viability of socially inclusive spaces, and encouraging the presence of social enterprises within the station, fostering a symbiotic relationship between commerce and community. Outside, by prioritizing pedestrian spaces outside stations, ensuring availability and accessibility, implementing inclusive place management, actively involving the city in space programming around the station, and collaborating with social enterprises to contribute to the overall social fabric of the station surroundings.

Impediments to these goals have been identified in the policy and governance boundaries. One significant impediment lies in the divergent policies and governance structures of railways and city administration. Bridging this gap is crucial for streamlined and cohesive urban development. Additionally, business and profit boundaries make the situation more difficult: high rent requirements for railway spaces often pose a challenge for social enterprises. Overcoming this financial barrier is key to integrating socially conscious ventures within station premises. To overcome the issue, it is crucial to demonstrate a “Social Business Case”, a strategic approach showcasing successful social projects that have proven to be economic drivers. By creating meet-up areas and demonstrating the subsequent boost in commercial engagement, the economic viability of social initiatives can become apparent.

When designing spaces of social interaction, a Place Management Organization is crucial and must include stakeholders such as real estate owners, developers, the city, and railways. Convincing the city of the advantages of social inclusion and making it a compulsory aspect of urban development can overcome governance challenges. Active Programming is another fundamental pillar when designing such spaces. Prioritizing pedestrians over other modes of mobility and investing in “active mobility”, including sports infrastructure, enhances social inclusion and dwell time.

In conclusion, it is necessary to allocate space for social activities and make a percentage of economic space affordable for social enterprises. It is necessary to advocate for strategic navigation within existing legal frameworks, negotiating for changes to promote social inclusion, and highlighting the social benefits to gain support from businesses and decision-makers.

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6 Core component III: Methodological toolkit

The methodological toolkit for applying the produced knowledge in the living labs, which is the third and last core component of the station model, was developed parallel to the fields of action. It is based on a modified version of the Cambridge value creation model (Bocken et al., 2013; Vladimirova, 2019), which aims at capturing the position of various stakeholder groups on specific topics and outlining new potentials via workshops. It combines the core components I and II and relies on the productive cooperation of relevant stakeholders for station development (identified through a comprehensive stakeholder mapping process) with appropriate participation and collaboration formats.

Using the seven fields of action and the according KPIs as a thematic basis, the stakeholders are called to develop solutions and strategies together, which allow the station to make a positive contribution to sustainable urban development. Furthermore, the stakeholders are called to identify the exact boundaries which prohibit or inhibit the direct realization of the proposed strategies. Such boundaries could be governance obstacles, spatial factors, or other topics. As a last step, the participants of the workshops are called to identify interventions that allow for overcoming these boundaries.

This approach allows for a clear definition of goals for each stakeholder and field of action, as well as for the identification of changes which must occur in order for the model to be implemented. Of course, depending on the local context and station characteristics, not all fields of action may be relevant for each railway station (the stakeholder structure can also differ for each field of action). However, if the relevance of the fields of action is not clear, the proposed methodology can further act as a tool to identify the the importance of each one for each specific case study.

In the second round of workshops (cf. chapter 5.1), we tested the proposed methodology using the IAB and consortium members as representatives of various stakeholder groups. According to the expertise of the participants, we built 10 groups (3-5 people including moderator), each one concentrating on one of the model fields of action (three fields were assigned to two groups each, due to the number of participating experts in these fields). In most cases the participants in the groups were mixed from the three categories of the first workshop round (railway and industry, academia and experts, cities and urban governance), thus representing different stakeholder groups and points of view. With the help of the moderator and on the basis of the assigned field of action, the participants collaboratively developed strategies and solutions, identified boundaries as well as interventions for overcoming them according to the proposed methodology. This process led to productive discussions, where different points of view were discussed and compared. Furthermore, the concentration on specific fields of action and the steering of the discussion toward strategies/solutions and challenges of their implementation proved to be a good way of developing tangible transformation paths for railway stations, which correspond to the real conditions and problematics.

As can be seen in the exemplary excerpt of a Miro board for the field of action “resilience and green-blue infrastructure (UGI)“ (cf. Figure 4.), the discussion during the workshops took place using a pre-defined board structure, where the moderator of each group documented the participants’ contributions (similar board structures were used for each field of action and group). The participants were also given access to the boards used and could add their own comments as well.

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As of now (November 2023), this methodology and board structure is already in use within the framework of the first RAIL4CITIES living labs, where all relevant stakeholders participate in online workshops and are asked to discuss specific fields of action using the methodological toolkit described above. During the next year, further activities in the living labs will provide us with valuable data which will allow us to refine and expand this toolkit, as well as guarantee its applicability and effectiveness in different European contexts.

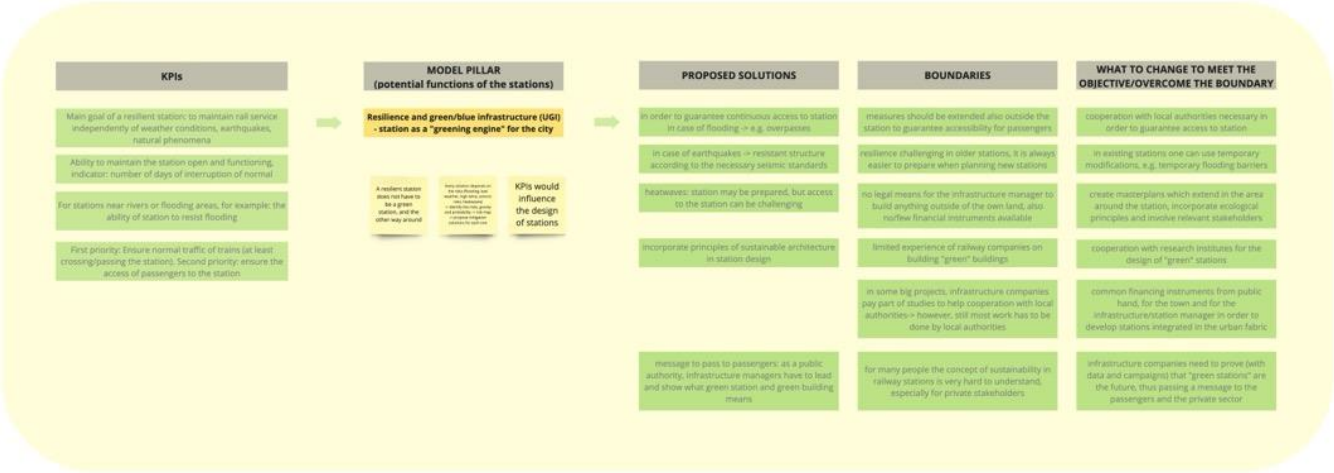

Figure 4. Excerpt from the methodology testing in the workshops.

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7 Discussion, outlook and further implications

European stations, with their unique position in the urban landscape as complex nodes of mobility as well as public places integral to the city (Bertolini 1998), have a huge untapped potential for sustainable development (Spinosa, 2023). However, to date, there is a lack of a consistent concept to describe railway stations, making it hard for all stakeholders involved to identify transition pathways to a more sustainable future. Within the RAIL4CITIES-project, we thus aim to find a common definition for European railway stations and to build a model for current and future railway stations that demonstrates the changes necessary to achieve this future. The challenge here is to find an approach that is useful for a vast array of stations while simultaneously being adaptable to local challenges and opportunities. In this report, we trace our approach on how to achieve such a model with three core components. For core component I, we reflect on various types and methods of station classification found in the literature and KPIs (chapter 3,4) to assist the evaluation of current and future stations, with fields of action (core component II) on aspects like mobility, energy or logistics (chapter 5). We furthermore present a methodological toolkit (core component III) to discuss these topics in order to identify the way forward – specifically suitable for each and every station context (chapter 6).

In our literature review, one can clearly notice that each system corresponds to rather specific purposes and aims. Since the railway industry has (at least until now) its focus on the management of station infrastructure and the provision of rail services, classifications developed by railway companies focus more on the stations themselves, as well as their users and their role as nodes in the transport system. However, the growing role of stations as intermodal mobility hubs and the gradual acknowledgment of stations being vital urban city elements is pushing classification methodologies into new directions, which include the characteristics of the context and the interplay of railway service with different modes of mobility and urban development as important criteria. This trend can be noticed in newer classification systems of the railway industry, as well as in most examples of the academic literature.

Based on the literature review as well as on the Urban Agenda of the European Union (2016), the SUMI, and the UN SDGs, we derived KPIs. Defining such KPIs is an important step in order to be able to assess current and future stations; however, our results show the difficulty in defining the KPIs in such a way that they can be used to compare progress between different railway stations due to vastly different conditions under which the stations operate. This leads us to the conclusion that in addition to quantitative indicators like the number of passengers passing through a station each day, qualitative indicators and relative assessments are of utmost importance.

The combination of the knowledge we acquired through the workshops and literature research led to the definition of seven fields of action which were proposed which show the way future railway stations could operate. These fields of action entail stations as a hubs of intermodal mobility, of circular economy, of energy, of logistics and of socially-inclusive services as well as the topics of resilience and green/blue infrastructure and station urban integration (TOD). Furthermore, we propose a method that entails discussing potential solutions for specific problems within each field of action as well as the exact boundaries which inhibit the realization of the proposed strategies and approaches to overcome said boundaries. Our results show the importance of including all relevant stakeholders with

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their manifold perspectives on what is of importance when discussing the station of the future. Additionally, we find that while diverse, there is a core set of values and topics that act as recurring factors, which we have therefore summarized in the model fields of action and methodology to apply the model.

In conclusion, the model consists of three core components (cf. Figure 5): First come the KPIs derived based on the literature and on expert knowledge, which help to measure the current status of a station as well as the future. The second core component are the seven thematic fields of action, showing the diversity of transformation pathways and roles for future railway stations. Third is the methodology of the model application in the living labs, which in turn gives an opportunity to adjust aspects of the model to the needs of the specific application context. Thus, the model is not a static image. On the contrary, it is rather a dynamic process, which – while addressing aspects derived from the UN SDGs that are relevant to stations all over the EU and thus having generic components – can be adjusted to the various local case studies based on necessities and challenges a station might face on-site.

In our next research steps, the three proposed core components will be systematically linked together. The produced knowledge on station classification can be used for the development of a new, inclusive model, whose classificatory components will be linked with specific KPIs, fields of action and application methods, thus allowing an identification and suggestion of sustainable development pathways for each different type of station. This linkage is necessary since the analysis has clearly demonstrated the different needs and conditions of station types depending on their characteristics and context. Developing a systematic approach which allows the identification and suggestion of appropriate strategies and indicators depending on the station type is thus a valuable addition to the existing strategic tools of station transformation and transit-oriented development. The application of this first version of the model in the different living labs will produce further relevant knowledge which can be used prospectively for developing this systematic approach.

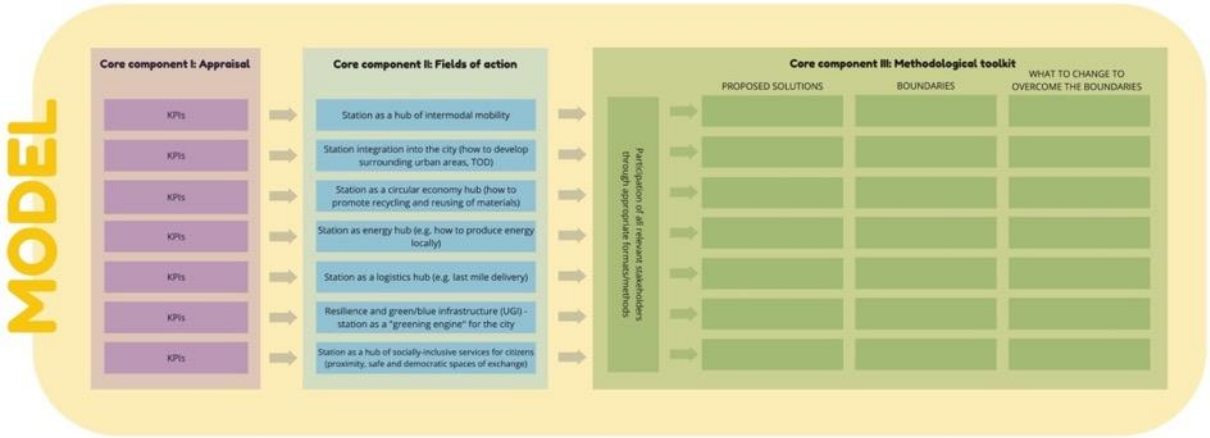

Figure 5. Overview of the derived model with the KPIs serving as a basis for the model fields of action, which can be discussed individually using the proposed method.

Reflecting on the first version of the station model presented in this document, it is always the price of generic concepts that, in order to guarantee wide applicability, they sacrifice the potential of providing exact solutions. We were aware of this when we began developing the station model. Thus, the produced results, while being generic in their nature (meaning not addressing any specific context), are solution-oriented and provide guidelines and strategies for the model implementation. Thus, the

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model for the railway station of the future remains on an abstract level and yet simultaneously addresses the variety of its implementation possibilities.

Throughout the development process, our main role as researchers has been to listen rather than to dictate, aiming to gain first-hand knowledge of the real problems and potentials, as well as the opinions of experts about the ways they can be solved. The diversity of our discussion partners and their valuable feedback gave us the opportunity to view the topic of railway stations and their potential in sustainable urban development from many different points of view, thus understanding the possible synergies and conflicts that may arise during the model implementation phase. While every expert group addressed different thematic points, they all agreed on the fact that cooperation and common engagement are needed in order to successfully use this theoretical model in practice. Thus, we can safely predict that the implementation of the model and the use of railway stations' transformation as an instrument for sustainable urban development is a common task, whose success highly depends on the willingness of the participating stakeholders to cooperate towards common goals. Proper stakeholder management and activation seems to be one of the most challenging tasks of the next phase of the RAIL4CITIES project, which is the application of the station model in the living labs and case studies across Europe, and with that the real-world testing of the proposals made in this report.

Specifically, the five living labs will become a testing ground for the fields of action proposed in the model (cf. chapter 5). The main focus of the Toulouse Matabiau living lab will be to explore how to transform the station into a green mobility hub promoting intermodality, and how to gain new potential users enabling them to switch from the use of cars to the use of active and green mobility. The Italian living lab in Milan Rogoredo will study a spatial, functional, and economic model of a station as an "energy hub", able to produce its own renewable energy, and offer fuel sharing and micro-mobility at the station and in its parking areas. In the Polish living lab (Tomaszów Mazowiecki), PKP and IBDiM aim to study a new model for stations that integrates multi-functional applications and services for social and urban inclusion, and furthermore to envision the connection between the station and the city centre through the use of green micro-mobility. The topic of the German living lab in Dorfen is the conceptual elaboration of urban development and transformation oriented towards public transport and accessibility (TOD). Furthermore, a summer school conducted in Dorfen will focus on various contemporary topics in sustainable urban development such as the design of mobility spaces, the integration of green-blue infrastructure and the social function of the urban fabric around the train station. Finally, the focus in the Belgian living lab in Ottignies will be the transformation of the station into a "hub of services", enabling 15-minute city neighborhoods by providing proximity services that are useful for the citizens' daily life, while making the station livable at all times of the day and night. Apart from the mentioned living labs, the station model and methodology can be tested in three additional case studies in Portugal, along the new high-speed rail line from Lisbon to Oporto.

Through the model application in the living labs and case studies, we will gain valuable data which will enable us to return to the drawing board at a later point and develop this model further, guaranteeing its wide applicability across the EU and having addressed the needs of the various regional and national contexts. In this way, the RAIL4CITIES project aims to produce a solid theoretical framework which will have been tested in practice, thus encouraging local stakeholders to dive deep into the available tools and strategies in order to explore the potentials of railway stations as promoters of sustainable urban development.

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