RAIL4CITIES

[Report on impact analysis methodology and tool setup]

Deliverable 2.2

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List of Abbreviations

AHP: Analytic Hierarchy Process
CBA: Cost-benefit analysis
CH4: Methane
CO: Carbon monoxide
CO_2: Carbon dioxide
dB: Decibels
EU: European Union
GHG: Greenhouse gases
KPI: Key performance indicator
Lden: Day-evening-night level
LL: Living Lab
Maas: Mobility as a Service
MCA: Multicriteria analysis
N_2O: Nitrous oxide
NO_x: Nitrogen oxides
NPV: Net Present Value
SAIT: Transport Investment Evaluation System
SNPV: Sustainable Net Present Value
SO_2: Sulphur dioxide
S-ROI: Sustainable return on Investment
T: Tonnes
ToC: Theory of Change
TOD: Transit-oriented development
UGI: Urban green infrastructure
VAT: Value-added tax
VoT: Value of Time

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1 Executive Summary

The aim of this deliverable is to develop the methodology for the impact analysis of new model of stations in the city. The developed methodology's goal is to compute the Sustainable Return on Investment (S-ROI), which accounts for the environmental and social factors in addition to the economic costs and benefits (CBA). To perform the cost-benefit analysis (CBA), *“Sistema d’Avaluació d’Inversions en Transport” (SAIT)* tool will be used. SAIT is widely used for Catalonia, Spain, to evaluate the new infrastructure development. As a result, this developed methodology will assess not only the effects on the stations' bottom line (cost-benefit analysis of integrating, for example, new services and solutions), but also the effects on the urban ecosystem (on people, the environment, transportation planning, and urban planning), particularly those that are not "directly tangible."

Three interrelated methodologies—the Theory of Change (ToC), a Sustainable Return on Investment (S-ROI), and a Multicriteria Analysis (MCA)—are designed to explain the assessment of the new station model's impact on the urban context and the mobility system in this deliverable. The ToC outlines the activities, solutions, and impacts (or KPIs) of each of the seven field of actions (field of actions defined in D2.1) while considering the boundaries and how to overcome them as well. The ToC must be carried out in WP3 in all living labs, serves as the foundation for both the S-ROI and the MCA. For each field of action, this deliverable thus offers a preliminary overview of the ToC, which will be further improved in the WP3 workshops with the cooperation of the Living Labs.

The objective of the S-ROI methodology designed in this deliverable is to obtain an objective indicator of the net contribution or overall benefit of each of the outputs to subsequently choose the optimal solution (in this case the output from the previous ToC methodology). The selection of optimal solution is made in conjunction with the results of the multicriteria analysis (MCA). The central idea is to develop a tool that provides the key solutions for each action to address economic, environmental, and social aspects. The impact analysis tool will allow for the construction of creative services and solutions that address social, environmental, and economic factors by integrating S-ROI and MCA.

This deliverable, a part of Work Package 2 (WP2), is concerned with setting up the project framework's impact assessment methodology, tools, and SCP model. This deliverable provides specifics on the effect assessment approach which will be deployed in WP3 during the operational period and each living lab's impact analysis will be evaluated in WP4. The generalized ToC for each filed of action described in D2.2 will be designed for each living lab and reviewed by stakeholders in WP3, and D4.1 and D4.3 in WP4 will quantify the effects using information gathered from the living lab databases at different WP2 and WP3 stages. Furthermore, the WP3 and WP4 will use the impact assessment technique developed in D2.2 to carry out impact studies at the living lab level.

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2 Introduction

This deliverable is part of WP2, which is dedicated to the definition of the SCP model, methodologies, and tools for impact assessment. This deliverable particularly, **D2.2**, **explains in detail the impact assessment methodology**, which will then be deployed during living lab operation in WP3 for the evaluation of the impact of the new model of stations in the city and WP4 for the evaluation of impact analysis tools for each living lab. The following Figure 1 illustrates in detail how D2.2 will be integrated with other deliverables and work-packages.

- The impacts which are identified in the Theory of Change in D2.2 will be reviewed by stakeholders in WP3 and then quantified in D4.1 and D4.3 in WP4 by using data from the database for each living lab which is collected at different stages in WP2 and WP3.
- The impact assessment methodology which is developed in D2.2 will be used in T3.5 in WP3 and WP4 for carrying out impact analysis based at living labs level.
- The spatial analysis being performed in T2.3 will be used in WP3.

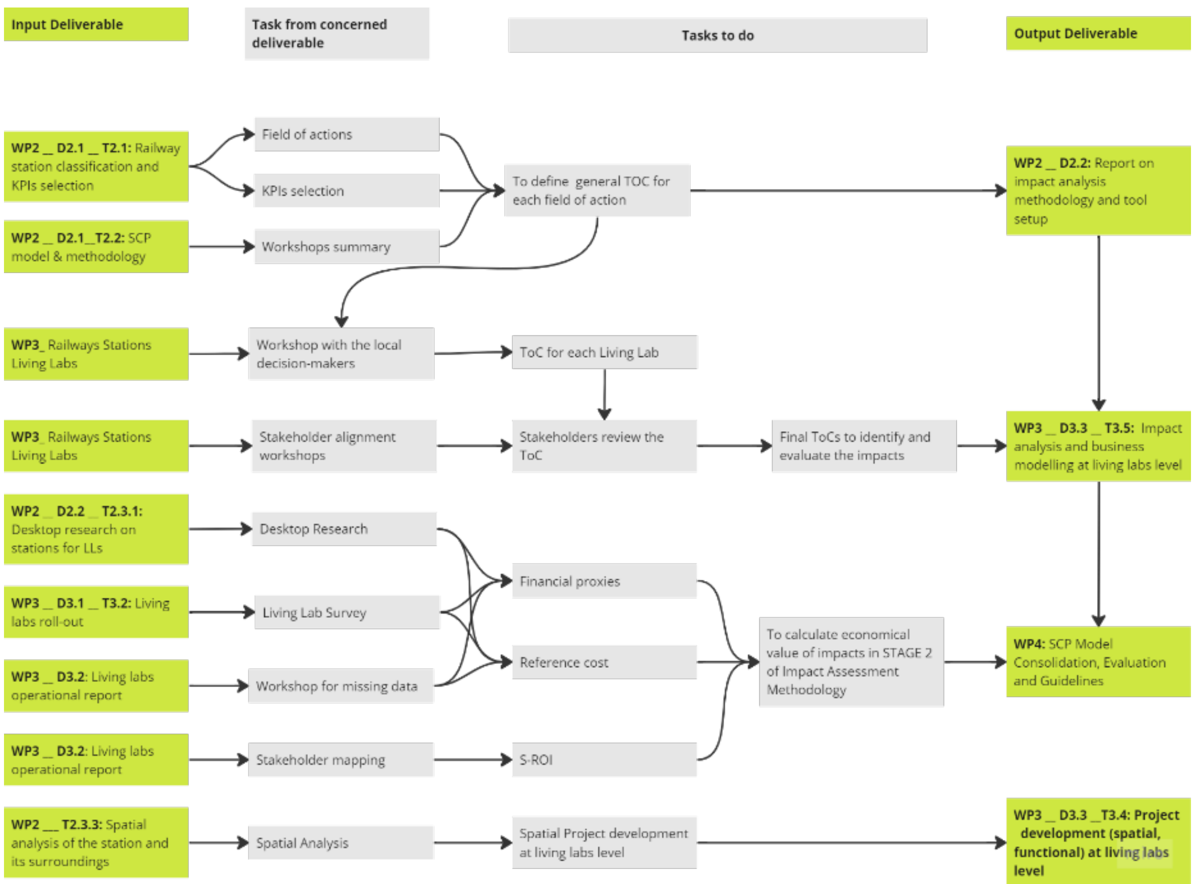

Figure 1: Integration of Work-Packages and deliverables.

In this deliverable, the **assessment of the impact** of the new station model on the urban context and on the mobility system will be explained, using **3 interrelated methodologies**: firstly, the Theory of change (**ToC**), secondly, a sustainable return on investment analysis (**S-ROI**) and finally, a multicriteria analysis (**MCA**).

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The basis for the S-ROI and the MCA will be the ToC, as it will provide the actions, solutions, and impacts (or KPIs) of each of the 7 actions to be implemented during the project in the different living labs. These fields of action have been elaborated in detail in "Deliverable 2.1, section 4.2: Results of fields of action development". The following seven fields of action have been defined:

1) Station as a **hub of intermodal mobility**
2) Station **integration into the city**
3) Station as a **circular economy hub**
4) Station as **energy hub**
5) Station as a **logistics hub**
6) Resilience and green/blue infrastructure (UGI) - **station as a "greening engine" for the city**
7) Station as a **hub of socially inclusive services for citizens**

The results of this report are not definitive, as there will be missing information to complete the ToC, this information will be collected during the different workshops that will be held in WP3. Therefore, this deliverable provides an initial outline of the ToC for each field of action that will be refined further with the collaboration of the Living Labs in the WP3 workshops.

The central idea is to develop a tool that provides the key solutions for each action to address economic, environmental, and social aspects. The impact analysis tool will integrate S-ROI and MCA and will enable the design of innovative services and solutions that address economic, environmental, and social aspects.

The **main objective** of this deliverable is to develop the methodology to **analyse the impact of the different actions that will be carried out in each railway station of the project**. Therefore, the **scope** of this report focuses, firstly, on the application of the ToC, which will help to **understand what changes are produced according to the different interventions**. And secondly, on the application (in parallel) of the S-ROI and the MCA **to identify which solution** (identified in the ToC) is **prioritised to be implemented first**, i.e. which one has a higher positive impact.

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3 Methodology

The methodology used to determine the impact that the different LLs will have depending on the action chosen can be seen in Figure 2.

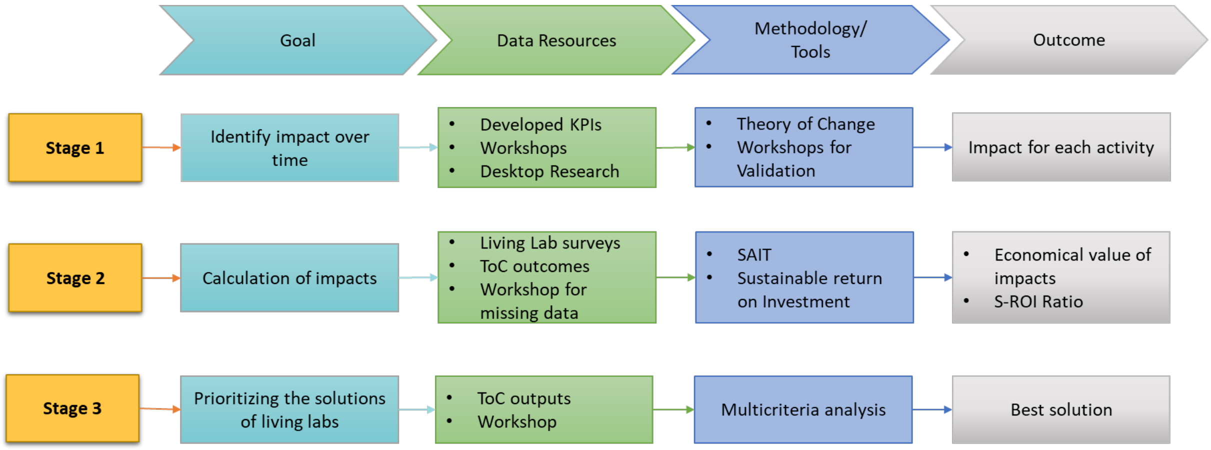

Figure 2: Methodological framework for the impact assessment.

Following the figure above, the steps to be taken are as follows:

- Stage 1: The Theory of Change (ToC) is performed here, which is used to detect the impacts (outcomes) of each action according to different time periods.
- Stage 2: Calculate the economic value of the impacts and the S-ROI ratio. Where impacts have been identified in the ToC.
- Stage 3: The last step is to prioritize the solutions of the actions to be implemented in the LLs, for which a multicriteria analysis is carried out.

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4 Impact Analysis Methodology

Due to its complexity, the impact analysis methodology requires several steps which allow the impact assessment to be comprehensive and specific to each LL scenario. These steps (referred to as "stages") will be explained in the following sections. There are 3 stages for the evaluation of the impacts of the new station model. These stages are interconnected with each other.

4.1 Stage 1: Identify Impacts

4.1.1 Goal

The goal of this stage is to identify the impacts of each proposed solution for each field of action over various time horizons (short, medium and long-term impacts). This also allows us to identify some indirect consequences and impacts.

4.1.2 Resources

In order to be able to develop the impact map (ToC), several KPIs have been defined. This was done through two different rounds of workshops with stakeholders. The results of these workshops can be found in "Deliverable 2.1, section 3.2: Results of KPI development". The workshops were conducted using a Miro-board to identify the possible KPIs and their solutions. By combining all knowledge acquired through the workshops and literature research, the seven fields of action which are mentioned above proposed as the base of the station model which describe the diversity of roles railway stations will have to assume soon. Furthermore, during the LL workshops, specific solutions will be proposed for each LL's field of action. The ToC maps will then combine these specific solutions with the KPI development and other inputs from D2.1.

4.1.3 Methods and tools: Theory of Change

The ToC explains how the activities undertaken by an intervention (such as a project, program or policy) contribute to a chain of results that lead to the intended or observed impacts. In this case, the ToC map (see Figure 3) presents the story of impacts for each field of action. Therefore, a separate ToC map will be generated for each field of action. A ToC map consists of activities, solutions, and outcomes.

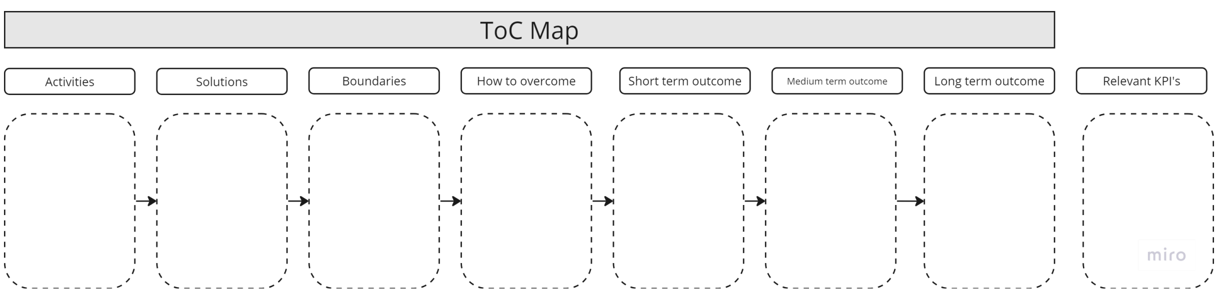

Figure 3: Format for ToC map.

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Activities

In the activities section, the inputs and activities for each field of action are defined. These are the activities that will be necessary to be carried out to achieve the potential solutions as defined in the workshops with stakeholders, which have been summarised in "D2.1, section 4.2", and the workshops with each LL elaborated in D3.1 Section 2.2.5 will explain the proposed potential solutions with expected boundaries as well.

Solutions

The solutions are the direct and tangible products from the activities step. These will be the proposed solutions which will be finalized in the workshops for ideating solutions in D3.1 with the LLs of each field of action. For example: a solution / proposed solution for the Circular Economy LL would be an established system for producing and reusing compost from organic waste (A solution proposed in ideation workshops in D3.1).

Outcomes (impacts)

The outcomes are indirect effects of the activities that occur for stakeholders as a result of the potential solutions while conserving boundaries. These are divided into short- (< 1 year), medium- (1-3 years) and long-term (>3 years) outcomes. The outcomes can be qualitative and quantitative. The outcomes may vary, either positively or negatively. It's crucial that the impact map (ToC) for each of the seven fields of action comprehensively outlines both possibilities.

Relevant KPIs

The KPIs are not a mandatory part of a ToC map. However, they have been included to show the relationship between possible proposed solutions and outcomes, and the KPIs that have been developed in D2.1 and by the stakeholders as well in the ideation workshops held in D3.1. In addition, these KPIs will be important in later stages of the impact assessment to quantify impacts.

4.1.4 Result

The focus of D2.2 in WP2 is to develop and prepare the methodology required for the project. This methodology includes the steps, procedures, and techniques that will be used to carry out the impact assessment of this project. So, the methodology is formulated in D2.2 which will be implemented in living labs during D3.2 in WP3. The results, findings, and insights gained from deploying the methodology in the living labs will be addressed in D3.2. As the theory of change (ToC) is a framework used to map out the connection of activities of this project and their intended outcomes. So, in D2.2 the general structure ToCs has been designed as a part of methodology for having the idea that how ToCs will be used in impact assessment. The ToC for station (Milano Rogoredo) is illustrated in this deliverable as an example that how the results of ideation workshops (held in D3.1) can be accommodated in ToC, which is designed in this deliverable D2.2. The final ToCs for each living lab will be finalized in D3.2 by using ToC structure from D2.2 and results of ideation workshops in D3.1. The ToC presented in this deliverable for the Milano Rogoredo station explains the activities and their proposed solution while considering the boundaries of those activities. The activities and their solutions respectively are generic as well, but in this ToC these activities and solutions are more specific for the Milano Rogoredo station. These are the activities which will implement on the Milano Rogoredo station for making the station liveable.

So, the outcome of this stage will be a general impact map (ToC map) for each field of action. As mentioned before, the workshops with stakeholders summarised in D2.1 and the ideation workshops

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with each LL in D3.1 will result in proposed solutions for each LL field of action that will be used to draw ToC for each defined field of action. A general ToC has been generated for the fields of action, which will be further developed when the ideation workshops will be completed for all LLs in D3.1.

The general ToC for each field of actions is explained below. These ToCs will be modified after the completion of ideation workshops in D3.1 accordingly. A ToC will address the proposed solutions form the respective activities at each LL while considering the possible boundaries. After the completion of workshops in D3.1, the next task will be to integrate all ToCs (concerning all 7 field of actions) which will be used in S-ROI analysis. So, this deliverable D2.2 will serve as baseline framework to work on the results of workshops, for their impact assessment.

1. **ToC of the "Circular Economy" applied to the Milano Rogoredo LL**

Figure 4 shows the ToC for the hub of circular economy. As mentioned earlier, this ToC is based on the results from ideation workshops in D3.1 so the proposed solutions discussed during the ideation workshops with the Milano Rogoredo LL while considering the boundaries and how to overcome these boundaries is illustrated in detail below.

As mentioned before, the field of action "Circular Economy" was applied in the context of the Milano Rogoredo LL. During the first workshops, several solutions were proposed, which can be organised into four main activities: research, waste management, use and reuse of (organic) waste, and stakeholder engagement.

Within the research activity, the solutions will be a comprehensive database of the station's material, energy and waste flows. This will allow the station fully to understand what are the areas that need attention and therefore identify potential areas for improvement, specific to the station's use case. This will ultimately allow for a more streamlined approach and efficient improvement of station's circular economy.

The waste management activity includes solutions such as specific monitoring systems and sorting systems. Improving and implementing sorting systems will encourage all stakeholders (e.g. station users and businesses) to engage in circular economy practices; while the monitoring systems will allow for better tracking of waste flows and will improve the waste sorting system, ultimately improving the recycling efficiency.

Once all waste flows are identified and minimized, the next activity is to use and reuse the remaining (organic) waste. During the workshops, the LL identified generating energy from organic waste, as well as producing compost as potential solutions (outcomes). This reuse of (organic) waste will not only decrease waste disposal and its related economic and environmental costs but will also allow the stations to become more energy and resource self-sufficient.

Lastly, stakeholder management and engagement are a vital activity, including close collaborations with local businesses and circular economy experts. Close collaborations are necessary for knowledge sharing and cooperation to improve the circular economy practices.

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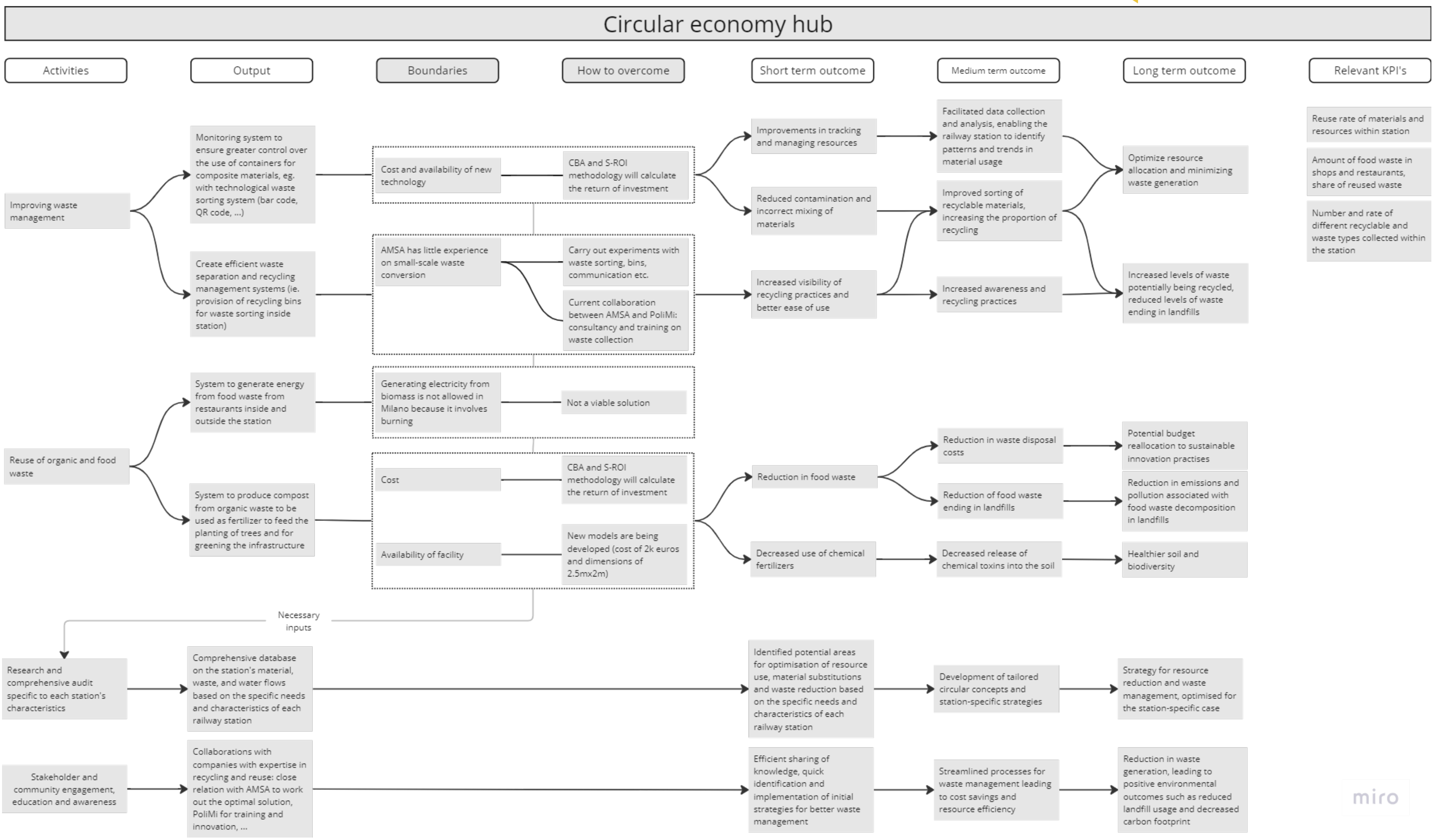

Figure 4: ToC of the “Circular Economy” applied to the Milano Rogoredo LL.

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2. ToC of the "Station as an Energy Hub" applied to the Milano Rogoredo LL

Figure 5 below shows the ToC for the station as an energy hub. As mentioned earlier, this ToC is based on the results from ideation workshops in D3.1 as well as the proposed solutions discussed during the first workshops discussed in D2.1 with the Milano Rogoredo LL.

As mentioned before, the field of action "Station as an Energy Hub" was applied in the context of the Milano Rogoredo LL. During the ideation workshop with the LL, several solutions were proposed with boundaries, which can be organised into four main activities: ensuring viability (in social, economic and legal terms), increasing the share of renewable energy, implementing innovative solutions, and improving energy efficiency.

Ensuring viability entails setting up close collaborations with experts as well as streamlining bureaucratic processes and alleviating legal impediments. These are necessary to ensure widespread adoption of green energy solutions. Furthermore, involving experts is necessary to ensure a cost-efficient application of solutions.

Furthermore, various forms of renewable energy generation are proposed (such as implementing solar panels, micro wind turbines, etc.). Although it is not yet clear which solutions will be viable for implementation in the Milano-Rogoredo LL, they give a general overview of the possibilities to increase the station's share in renewable and locally produced energy. This will increase the energy self-sufficiency of the station and decrease its reliance on non-renewable sources of energy, ultimately decreasing the emissions related to energy production. These objectives will be additionally addressed through the implementation of innovative solutions such as renewable energy benches and photovoltaic lockers to charge customer devices, while simultaneously improving customer satisfaction.

Lastly, it is suggested to improve the building's energy efficiency by improving its insulation and air circulation through renovation projects. This will in the first place decrease the building's energy consumption and ultimately lead to lower emissions and energy costs.

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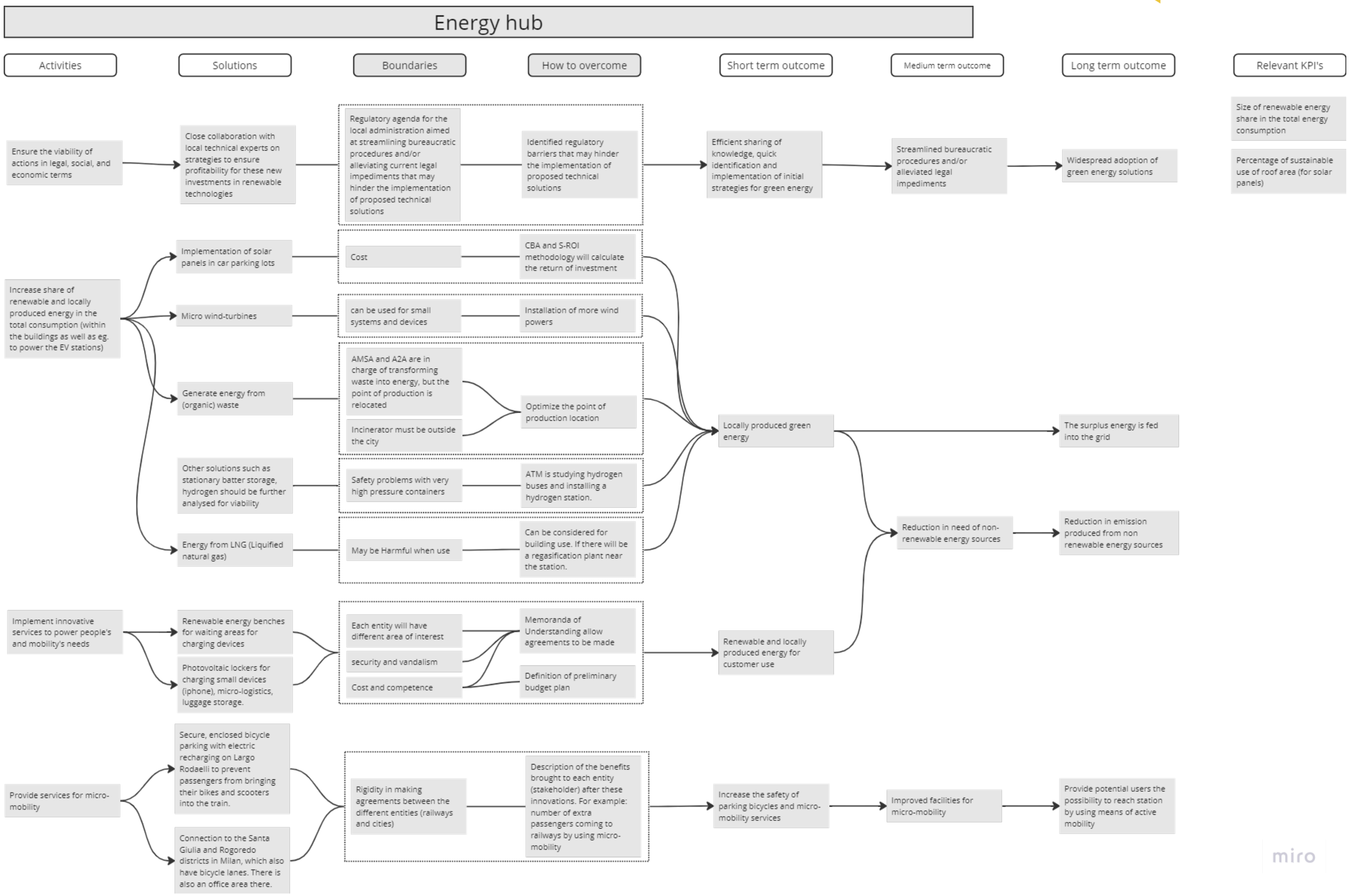

Figure 5: ToC of the “Station as an Energy Hub” applied to the Milano Rogoredo LL.

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3. **General ToC for “Station as a hub of intermodal mobility”**

The summary of ToC for Station as a hub of intermodal mobility is explained below:

- Enabling the digital integration of multimodal transportation activities involves providing information about bike rental facilities at destination railway stations and integrating this information into public transport applications. This includes incorporating schedules of public transport, Mobility as a Service (MaaS), taxi rental information, and micro-mobility options.
- Reconfiguring the spatial layout of railway station areas to facilitate multimodal transportation activities involves implementing secure parking for bikes and micro-mobility devices, introducing Park & Ride facilities at stations, enhancing bicycle lanes, and optimising sidewalks through efficient curb space management.

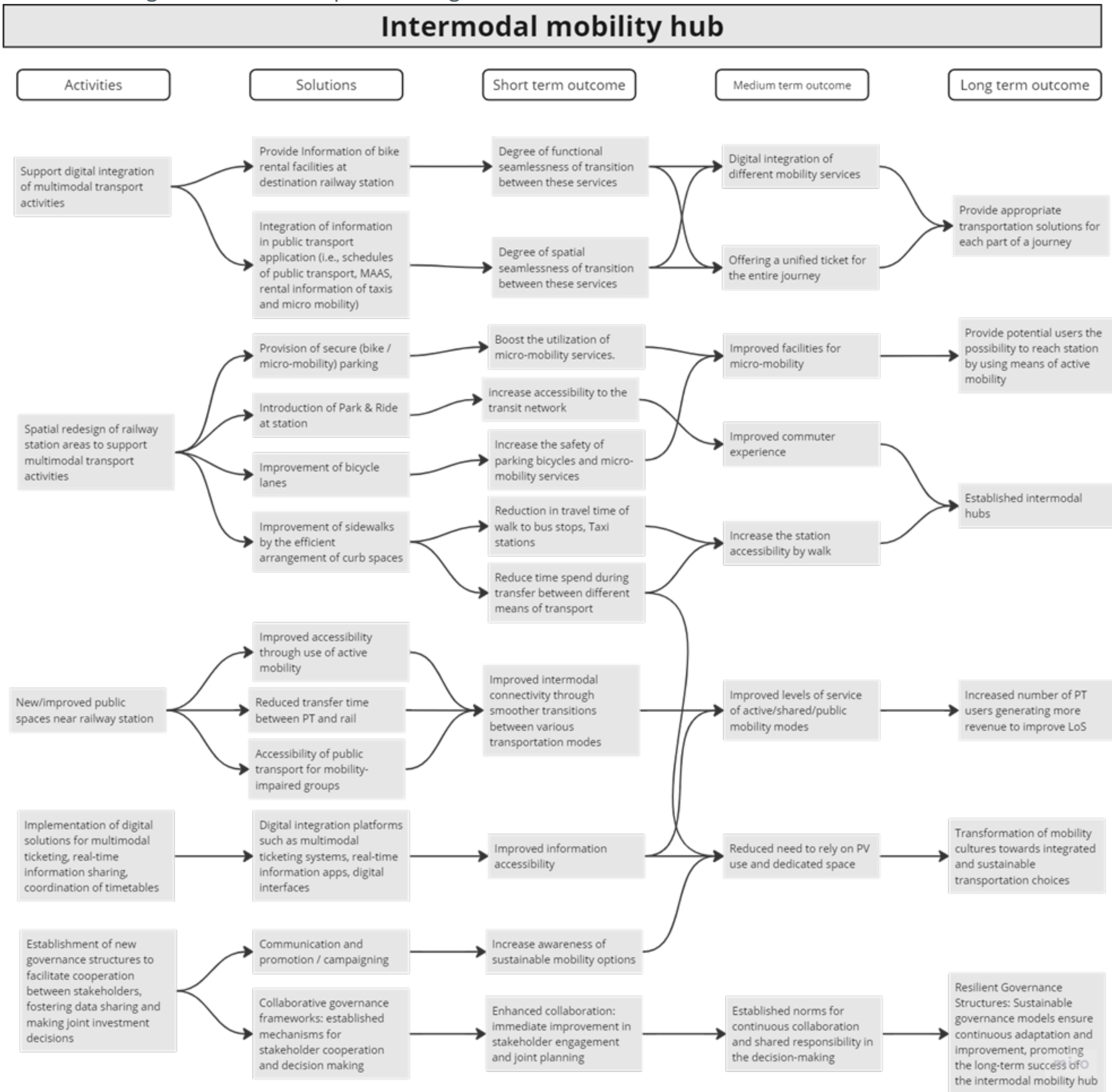

Figure 6: General ToC of the “Station as a hub of intermodal mobility”. General ToC for “Station integration into the city”

- Enhancing or creating new public spaces near railway stations will enhance accessibility through the promotion of active mobility, reduce transfer time between public transportation and rail services, and improve accessibility to public transport for individuals with mobility impairments.
- Deploying digital solutions for multimodal ticketing, real-time information dissemination, and timetable coordination will offer digital integration platforms like multimodal ticketing systems, real-time information applications, and digital interfaces.
- Creating new governance frameworks to foster collaboration among stakeholders, promote data sharing, and facilitate collective investment decisions will result in collaborative governance structures: established mechanisms for stakeholder cooperation and decision-making.

The summary of ToC for Station integration into the city is explained below:

- Connecting high-speed rail stations with existing urban centers, particularly when stations are situated outside of the city, serves several important purposes. It ensures that:
    - The railway station is in close spatial proximity to public transportation networks, enhancing accessibility for passengers and encouraging the use of public transit.
    - Rail travel becomes a more competitive option compared to other modes of transportation, thanks to its convenient connection to urban centralities.
    - The integration influences patterns of urban development, fostering growth and activity around the station area, and promoting sustainable and vibrant communities.
- Establishing high-quality new urban centres around railway stations located outside of cities will lead to an increase in trip generation and distribution from these stations. This strategic development approach maximises the utilisation of transportation infrastructure and enhances the overall efficiency of rail services. By creating vibrant hubs with diverse amenities, mixed-use spaces, and improved connectivity, these urban centres attract a greater volume of commuters, residents, and visitors. As a result, the railway stations become focal points for increased activity, contributing to higher ridership numbers and a more sustainable urban ecosystem.
- Collaboration between railway companies, urban governance entities, and private stakeholders presents a unique opportunity to foster increased opportunities for socializing and community building, while simultaneously ensuring equitable development around railway stations. By working together, these diverse stakeholders can leverage their respective expertise and resources to create vibrant, inclusive environments that cater to the needs of local residents and businesses.

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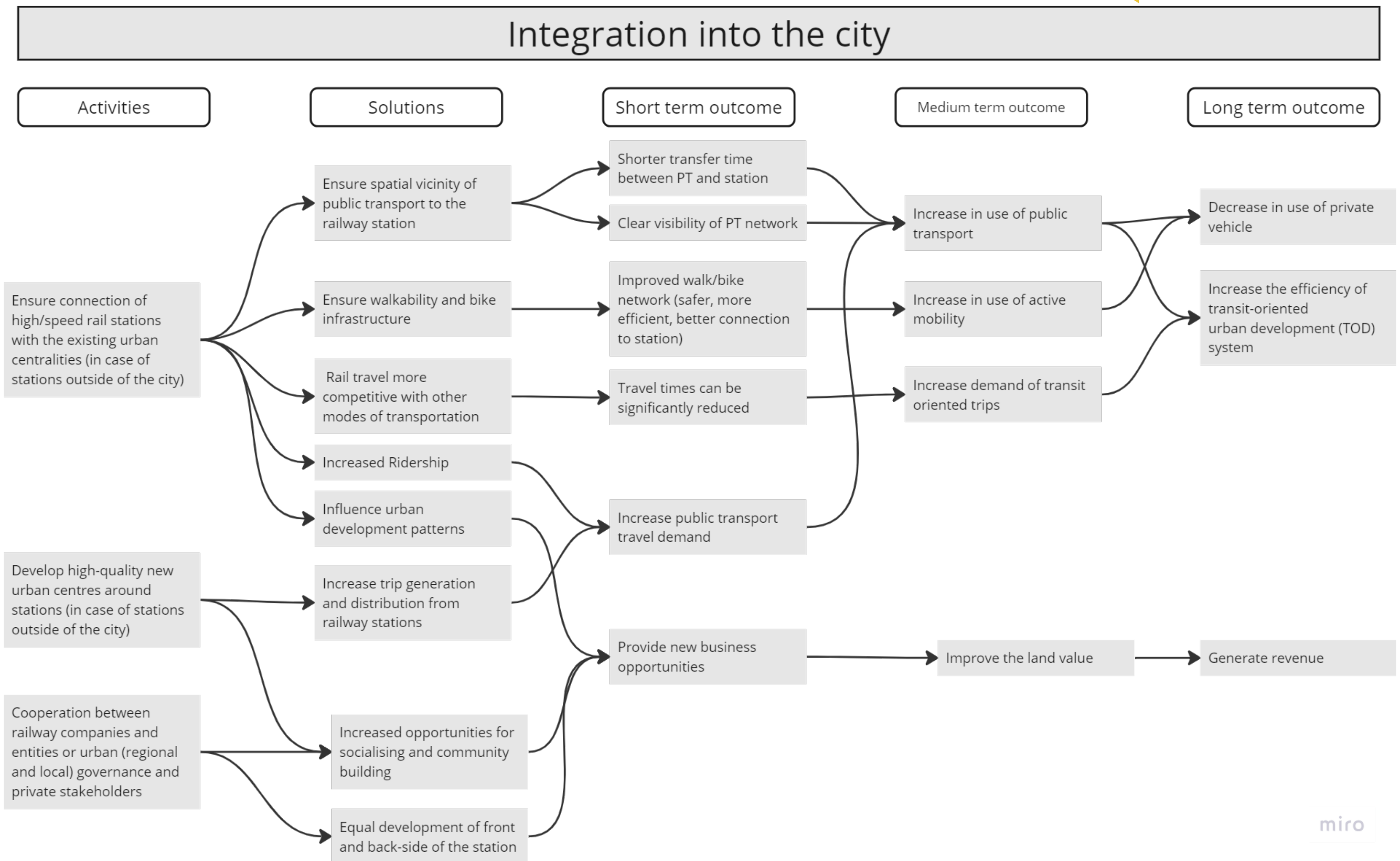

Figure 7: General ToC of the "Station integration into the city".

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4. **General ToC for "Station as a logistics hub"**

The summary of ToC for Station as a logistics hub is explained below:

- Incorporating logistics functions into the station's business model will lead to the establishment of a multimodal logistics hub, as well as the provision of parcel lockers and basic storage facilities.
- Establishing public-private partnerships (PPPs) for railway companies to bring goods/packages to the station will lead to investments in railway infrastructure. This includes enhancements such as improved station facilities, platforms, and cargo handling equipment.
- Implementing dynamic curb management, which includes dedicated lanes for cargo bikes and other delivery vehicles like electric vehicles (EVs), will encourage innovation in sustainable logistics solutions. This encompasses the development of electric delivery vehicles, alternative fuels, and smart delivery technologies.

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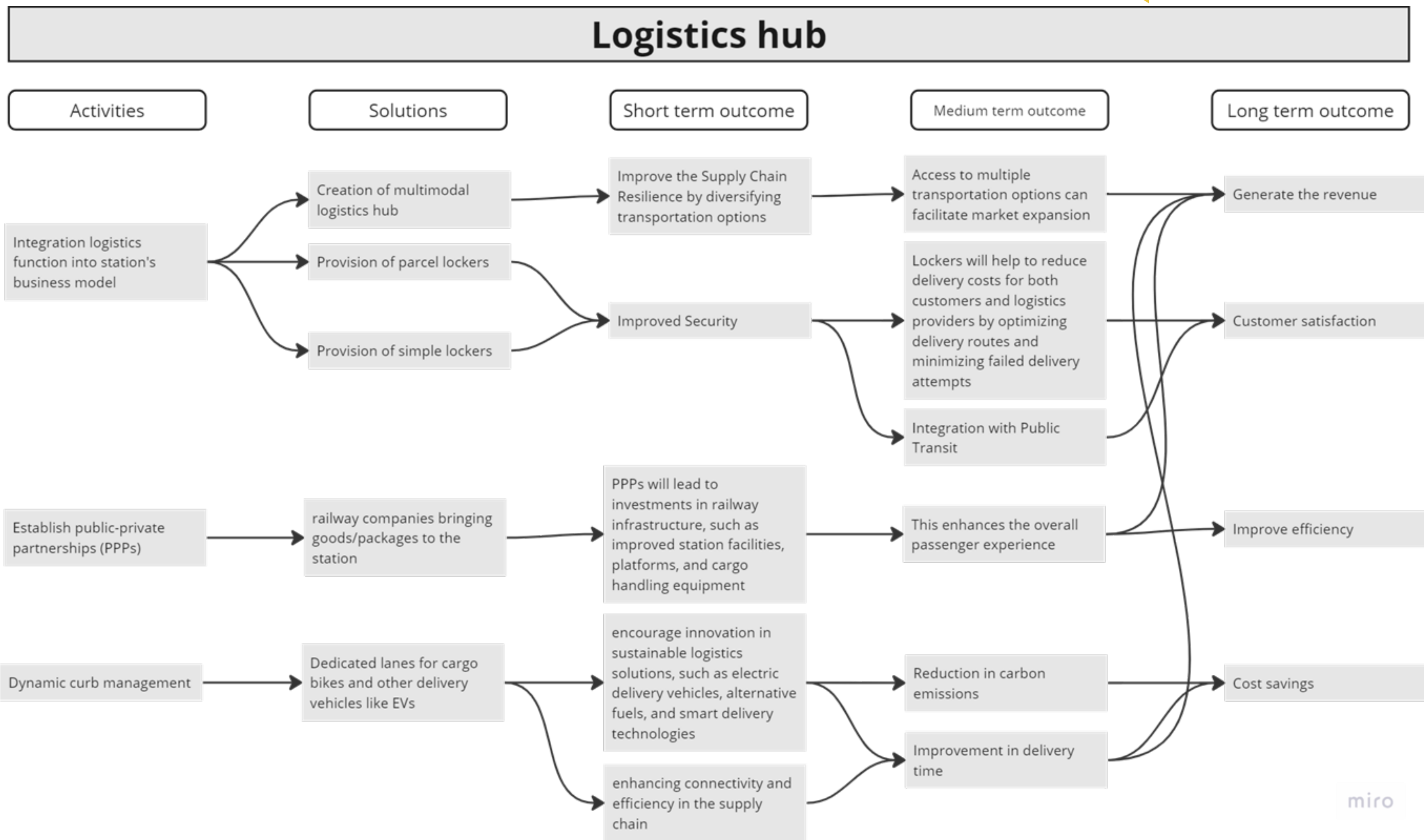

Figure 8: General ToC of the “Station as a logistics hub”.

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5. **General ToC for "Resilience and green/blue infrastructure (UGI) - station as a "greening engine" for the city**

The summary of ToC for station as a "greening engine" for the city is explained below:

- Conceiving and implementing larger-scale plans involving the transit-oriented redevelopment of entire station areas and/or their connection to surrounding centralities of railway stations will lead to the transformation of sustainable land use, as well as the development of new building facades and public spaces.
- Adopting suitable design and construction standards in new railway stations will entail the implementation of measures such as building overpasses to mitigate flooding risks.
- Implementing transit-oriented urban development principles at railway stations involves allocating spatial resources, such as parking spaces and streets, for the development of ecological infrastructure. Additionally, it includes efforts to increase the walkability of public spaces.
- Implementing nature-based solutions at railway stations will involve the creation of green facades and roofs, as well as the establishment of natural water retention areas.

6. **General ToC for "Station as a hub of socially inclusive services for citizens"**

The summary of ToC for Station as a hub of socially inclusive services for citizens is explained below:

- Social infrastructure planning at railway stations entails increasing spaces for seating without obligation to consume for people, ensuring accessible infrastructure for people with disabilities, and providing areas for kindergarten facilities.
- The presence of ongoing participatory processes for designing the station and its surrounding areas, along with active citizen engagement, will result in launching design competitions and organising workshops to gather community feedback.
- Assessing the social quality of spaces at railway stations will prioritize actions such as ensuring ample space for pedestrians outside the station, implementing active space programming, and integrating sports infrastructure.
- The implementation of various strategies, such as the Middle-Up-Down strategy, at railway stations for social inclusion aims to facilitate meetings between the community, real estate companies, and railway companies and involves the citizens in decision making.

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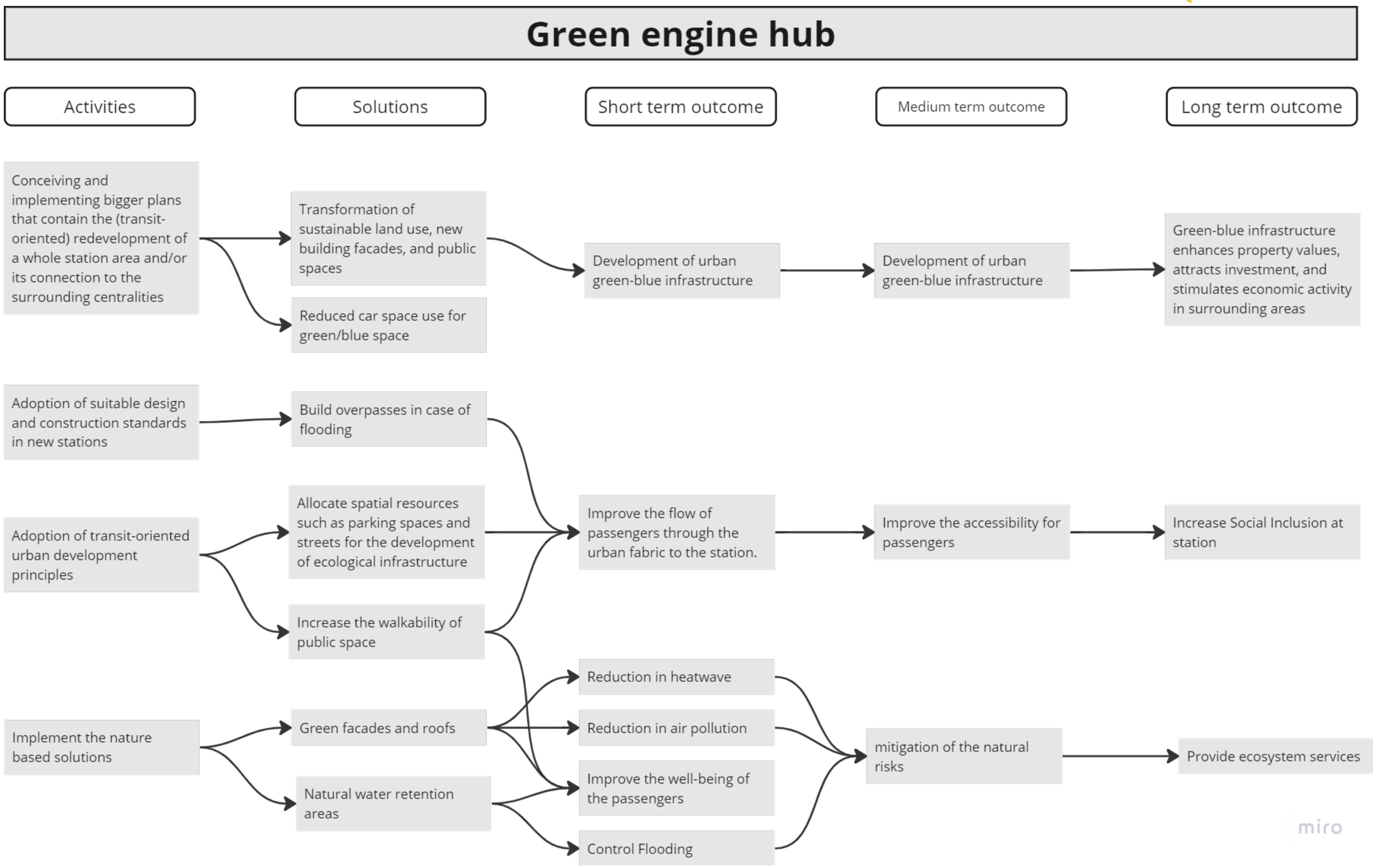

Figure 9: General ToC of the "Station as a greening engine for the city".

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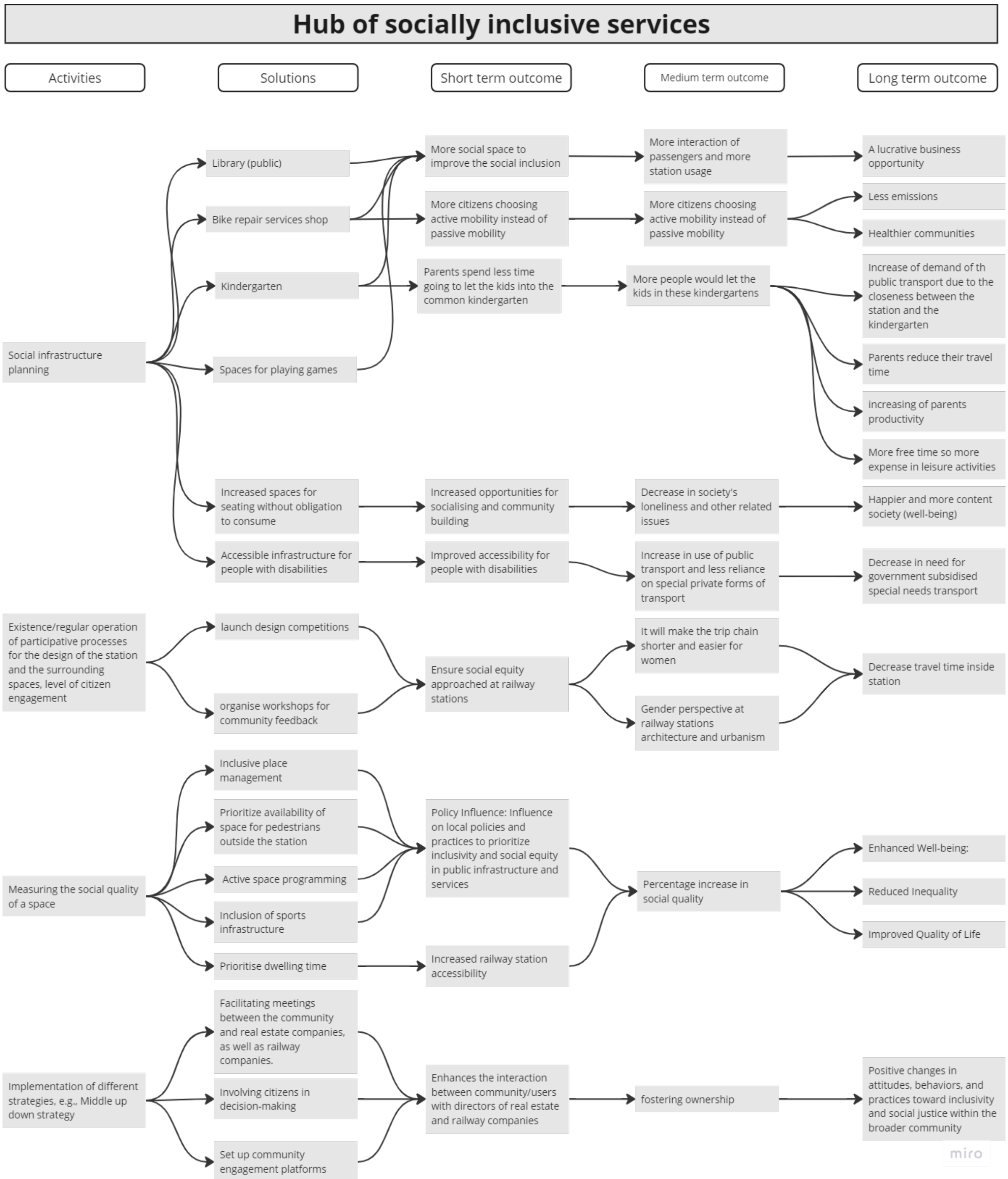

Figure 10: General ToC of the “Station as a hub of socially inclusive services for citizens”.

__Next Steps for making ToCs for each living lab:__

The above mentioned general ToCs are providing the baseline framework for generating the ToCs for respective each field of action in WP3. After the completion of D3.1 (ideation workshops), ToCs for each field of action will be designed addressing the solutions with boundaries from the different activities at living lab level. After designing all ToCs the next step will be the integration of these 7 ToCs for the Impact Assessment in WP3.

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4.2 Stage 2: Calculation of Impacts

The present section aims to calculate the impacts of each action taken on the new models of railway stations in the urban context and mobility system using the Sustainable Return on Investment (S-ROI) methodology. The S-ROI is an investment evaluation approach that seeks to measure the financial performance and environmental and social impact of an investment with the aim of determining its long-term sustainability assessed in economic terms.

The S-ROI goes beyond simply calculating the financial return of an investment. It also considers the positive or negative effects that an investment can have on the environment and society. In this way, it seeks to comprehensively evaluate the economic, social, and environmental benefits generated by an investment.

The benefits or impacts of the S-ROI methodology in areas such as economic, social, environmental and sustainable can be addressed as follows:

- **Economic Impact:** The S-ROI methodology can help identify and quantify the economic benefits of a social investment, such as job creation, increased labour productivity, stimulation of local and regional economic growth, and reduction of costs associated with social issues like health.
- **Social Impact:** In the social sphere, the S-ROI methodology can evaluate the impact on people's quality of life, social inclusion, equal opportunities, community cohesion, improvement of education and health, as well as reduction of poverty and social exclusion.
- **Environmental Impact:** S-ROI can help measure positive effects on the environment, such as reducing greenhouse gas emissions, conserving biodiversity, protecting sensitive ecosystems, sustainable management of natural resources, and promoting environmentally friendly practices.
- **Sustainable Impact:** S-ROI also allows evaluating the long-term sustainability of social interventions, considering aspects such as intergenerational equity, long-term economic viability, resilience to environmental and social changes, and adaptability to changing community needs.

These four fields represent fundamental areas where the S-ROI methodology can provide a more comprehensive understanding of the social and economic value of social investments and actions, enabling more informed and impact-oriented decision-making.

The objective of the S-ROI methodology is to obtain an objective indicator of the net contribution or overall benefit of each of the solutions to subsequently choose the best solution (in this case the Solution from the previous TOC methodology). This selection is made in conjunction with the results of the multicriteria analysis (MCA) described in the next section of this document. The goal is to obtain two parallel analyses from two different perspectives:

- **MCA**: Analysing how the different proposed solutions or solutions for each Living Lab fields of action align with specific and particular objectives of the stakeholders.
- **S-ROI**: Obtaining the net contribution or overall benefit in economic, social, environmental, and sustainable terms of each solution.

Below, in Figure 11, the proposed workflow for implementing the S-ROI evaluation of the activities proposed in the living labs is represented.

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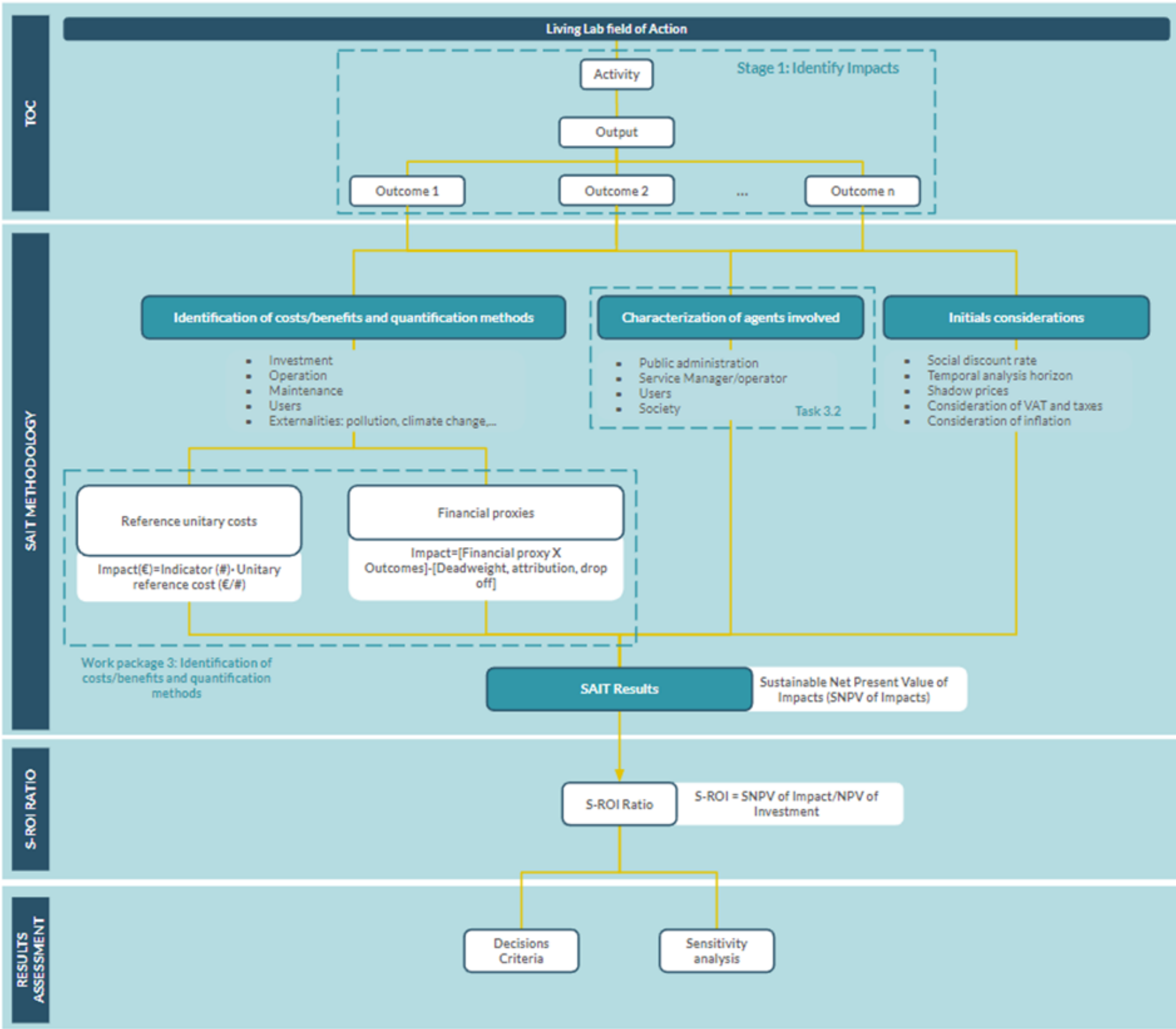

Figure 11: Workflow for implementing the S-ROI evaluation of the activities.

Building on the previously outlined ToC, activities or actions are generated for each of the Living Labs' initiatives to be implemented (Stage 1: Identify Impacts). Each of these actions yields multiple solutions, which, in turn, result in short, medium, and long-term outcomes. These outcomes serve as inputs for our S-ROI evaluation. In essence, each outcome will undergo monetization to ascertain the net benefit of the Solution. It is noteworthy that this analysis, as depicted in the scheme, will be conducted for each of the proposed solutions. Subsequently, from each solution, the net benefit and investment value will be determined, aiming to compute the respective S-ROI ratio.

As shown in the previous graph, the result of the S-ROI ratio is expressed as:

$$S-ROI = \frac{\Sigma\ SNPV\ of\ Impacts}{Value\ of\ Investment\ for\ each\ Solution}$$

Consequently, it is proposed to obtain the value of $SNPV\ of\ Impacts$ (Sustainable Net Present Value of Impacts) through the SAIT methodology. SAIT is used to analyze and compare different transportation projects, considering factors like expected demand, construction and operation costs, environmental and social impacts, as well as the economic and mobility benefits each project would generate.

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As the S-ROI methodology also takes into account sustainability aspects, the procedure has been adapted to align it with the objectives of the current project. The following section details each of the proposed steps in the methodology.

Lastly, in addition to the necessary evaluation of the outcomes obtained, which will indicate the amount of social, environmental, and sustainable benefits generated per unit of investment in the solution, a sensitivity analysis is intended to be conducted. The aim is, on one hand, to detect the most sensitive parameters and, on the other hand, to observe how the result varies with small variations in these parameters.

Subsequently, in the following sections, a more detailed explanation of each of the described processes is provided, starting from the monetization processes to the sensitivity analysis and results attainment.

4.2.1 SAIT Methodology

The Transport Investment Evaluation System (SAIT) is a method used to evaluate investments in the transportation sector, specifically employed in Catalonia, Spain. This system is applied to assess the feasibility and impact of transportation infrastructure projects such as roads, railways, public transportation systems, among others.

SAIT is used to analyse and compare different transportation projects, considering factors like expected demand, construction and operation costs, environmental and social impacts, as well as the economic and mobility benefits each project would generate.

Transport investment evaluation is crucial for making informed decisions on how to allocate financial resources and develop infrastructure to enhance efficiency and quality of life, while minimising negative impacts on the environment.

SAIT provides a structured and systematic framework for evaluating the profitability and impact of transportation projects, assisting decision-makers in selecting the most suitable investments and prioritising those that generate greater benefits for society and the environment.

For the proper use of the methodology with the purposes outlined in the current project, the following sections have been developed to detail the proposed steps of the methodology.

1. Introduction to socioeconomic evaluation
2. Initial considerations of the SAIT methodology
3. Characterization of the agents involved
4. Identification of costs/benefits
5. Aggregation of costs and benefits (discount rate)
6. SAIT results

Below, these principal steps of the SAIT methodology are furtherly detailed.

1. Introduction to socioeconomic evaluation

Socioeconomic evaluation is materialised through the performance of cost-benefit analysis (CBA hereafter), in which monetary values are assigned to the benefits and costs of the activity in the various years of the activity cycle, thus allowing the generation of cash flows from which indicators quantifying the investment's profitability can be obtained. This makes it possible to determine whether it is

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sufficiently significant to offset the opportunity cost (definition below) of the resources required for its implementation.

OPPORTUNITY COST
The opportunity cost of a good or service is defined as the potential gain from the best alternative that is foregone when a decision must be made among mutually exclusive alternatives. Therefore, the opportunity cost of an action will be equivalent to the benefits that could potentially have been obtained by allocating those resources to meet other needs. A project would increase social welfare only if the benefits derived from it are greater than the opportunity cost of the resources used.

2. Initial considerations of the SAIT methodology

Below are the initial considerations to take into account, as determined by the SAIT methodology:

- **Definition of the time horizon for socioeconomic analysis:** For economic analysis, the time horizon of an investment project is the period during which the effects associated with each of the agents affected by its implementation are evaluated. To ensure coherence in the analyses, the time horizon for economic analysis should coincide with that adopted for financial analysis.
  For our specific case, the analysis time horizon will be customised for each solution. If the solution involves the implementation of a tangible product or entity, like solar panels, the analysis will span the estimated or expected lifespan of these solar panels. Conversely, if the solution lacks a physical component and represents an activity or service, such as a social integration program for disadvantaged individuals, the horizon will encompass the entire duration of that project or service.
- **Consideration of inflation:** Unlike financial analysis, constant (real) prices will be used for economic analysis, i.e., fixed prices based on a base year and without considering inflation.
- **Social discount rate:** The discount rate is used to calculate the Net Present Value of the project (NPV) and incorporates to some extent a certain social vision of how future project effects will be valued relative to the current situation. This rate is set at 3%, following European guidelines.
- **Consideration of VAT and taxes:** In general, all monetary values estimated in relation to economic effects must be considered exempt from VAT or any other indirect tax. Even in this case, any other type of taxes should be eliminated. According to the European Commission's guidelines, analyses should be conducted without VAT if it is recoverable by the project promoter. On the contrary, when VAT is not recoverable, it must be included.
- **Shadow prices:** Unlike financial evaluations, market prices are not suitable for economic evaluation; instead, shadow prices should be used, reflecting the opportunity costs of cost concepts and consumers' willingness to pay for benefits. Distortion may result from market inefficiency or, in the case of public goods, because their fees do not reflect costs.

3. Characterization of the agents involved

The objective of this section is to classify the stakeholders involved in each of the proposed Solutions, whose identification falls under the WP3, in Task 3.2. In an activity of this nature, the involved stakeholders could be classified as:

- **Public Administration:** it is the total or partial owner of the assets, finances the project entirely or partially through public funds available at various administrative levels (local, supramunicipal, regional, state, EU).

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- **Service Manager/Operator:** this is the entity that manages and operates the service, whether or not it owns it, and can be both public and private. It typically has its own sources of income such as fees for the use of the service.
- **Users:** they are the consumers of the services offered by the Solution.
- **Society**: it is the set of 'society' affected by externalities according to the scope of the project or market on which it operates (how far the costs and benefits of the intervention reach).

However, this classification may be subject to changes in the future. As Solutions that need to be carried out and stakeholders become clearly identified, this proposed classification list can be modified to achieve a more accurate classification that better suits the proposed Solutions.

4. Identification of costs/benefits and quantification methods

The costs can be quite diverse. To ensure the proper social, economic, environmental, and sustainable evaluation of the proposals, all costs related to any environmental impact generated by the asset or service throughout its life cycle must be included.

it is proposed to classify the costs and investments of the Outcomes according to:

- **Investment costs:** the investment costs include: the acquisition, construction, renovation, or improvement of infrastructure as long as it increases the asset's useful life.
- **Operation:** the operating costs include all expenses related to the operation of services. These costs are generally direct expenses that depend on the level of activity (variable costs) and/or, if disaggregated information is not available, fixed expenses independent of the service provided but related to resources that are strictly necessary for the development of the main activity.
- **Maintenance:** maintenance costs include those expenses related to ensuring the proper operating conditions of the assets used in the services.
- **Users:** the benefit they obtain is measured from the consumer surplus, which is defined as the excess of willingness to pay by the user over the cost of the usage.
  The costs for users can encompass various aspects, including the reduction in travel times, quantified economically through the Value of Time (VoT), improvement in ease and comfort in carrying out their daily activities, impact on health through the implementation of measures that promote active mobility, or any other concept that directly affects the service user. As more Solutions are incorporated to quantify the impact in future stages of the project, additional and more specific costs and benefits for users can be included to better quantify the impact on them.
  It should be noted that the Value of Time (VoT) is a critical parameter for which specific studies with a high level of detail would be required for each project. Values from other studies can be adapted as long as they are comparable situations.

- **Externalities:** throughout the life cycle of a service or project, positive or negative effects on third parties can be generated, which may or may not be making use of them. These effects are known as externalities as they are not internalised by those who produce them in their decision-making. Calculating them is complex as market prices for externalities are rarely available and depend largely on multiple variables of a local nature where they are generated. Therefore, their economic value cannot be directly measured and must be calculated using indirect methods. An example of these methods is "contingent valuation", which is based on the willingness of those affected to pay to avoid/accept suffering these damages through surveys of stated preferences in hypothetical situations. Another method worth noting is

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"hedonic pricing", which assumes that the price of the externality can be inferred through its impact as an explanatory variable in the price of another good for which market prices are available; where variations in property prices are the most evident. However, in the common practice of Cost-Benefit Analysis (CBA), standardised unit costs from specific studies.

For the proper evaluation of the sustainability of the proposed actions or Solutions, it is proposed to assess the following externalities:

- **Pollution:** The cost of pollution is determined by the economic loss generated by the impact of a certain dose of contaminants on human health (reduction in life expectancy), ecosystems (reduced agricultural production), and building deterioration (maintenance and repairs). Among them are sulphur dioxide (SO_2), nitrogen oxides (NO_x), and carbon monoxide (CO). In particular solutions, the measurement of the impact of other pollutants can be adopted.
- **Climate change:** is caused by emissions of greenhouse gases (GHGs) such as carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4), which lead to a rise in temperatures resulting in a significant impact on climate and the dynamics of meteorological phenomena.

  To assess this impact, it is necessary to consider both direct emissions during the operation of the service and indirect emissions resulting from upstream and downstream processes (manufacturing, maintenance and dismantling, construction, and maintenance of infrastructure or materials required for assets).
- **Noise:** refers to any sound of volume, intensity, or duration that causes physical or psychological harm to those affected, resulting in economic losses derived from the disruption caused (restrictions on leisure activities or lack of comfort), health effects (medical expenses, loss of productivity, and increased mortality), and the devaluation of properties adjacent to the emission source.

  From the level of exposure to the equivalent noise throughout the day ($L_{den} \geq 55dB$) and the response functions to it, the proportion of affected users is determined. This proportion is then multiplied by the cost per person-year associated with the noise level.
- **Landscape:** actions that modify or degrade the landscape represent a loss of landscape or recreational value that can be included in the CBA, although their valuation can be highly subjective and closely linked to the specific location where the project is carried out. To indirectly assess this cost, studies of stated preferences can be conducted, or the willingness to pay for the cost of travel to the point of interest can be used as an indicator.
- **Liberation of public space:** refers to the process of reclaiming or repurposing areas that were previously dedicated to private vehicles or other limited uses for broader public enjoyment and sustainable urban development. This could include initiatives such as transforming streets into pedestrian zones, creating urban parks, expanding sidewalks, or implementing bike lanes. The goal is to enhance the quality of urban life, promote social interaction, improve mobility options, and mitigate environmental impacts by reducing reliance on cars and promoting alternative modes of transportation.

These proposals can be adapted and even supplemented with others as the project progresses and there's a better understanding of the activities or solutions to be implemented. To achieve a comprehensive understanding of sustainability analysis, it is recommended to conduct a life cycle assessment of each of the Solutions. This allows for the incorporation of all costs associated with any environmental impact generated by the asset or service throughout its life cycle.

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Obtaining these costs and benefits is key to achieving the expected social impact of the S-ROI methodology. During WP3 the collection of these costs will take place. To quantify these Outcomes, two options are proposed, depending on the level of information available during the process of monetizing the impacts and the nature of the Outcome.

I. Option 1: Unitary costs of reference

Unitary costs of reference costs are the standard costs assigned to each unit of measurement of a product or service. These costs provide a basis for calculating the total cost of a project, activity, or operation.

Some examples of unitary reference cost include:

- Cost per ton of CO2 emitted: €/T CO2
- Cost of investment and/or maintenance of solar panels: €/m2
- Cost of investment and/or maintenance of bike lanes or bus lanes: €/km
- Value of users' time (VoT): €/h

As mentioned earlier, finding these prices for monetizing the outcomes will be carried out in WP3. To do this, existing literature can be consulted, or local entities or administrations that already have these prices can be approached.

Finally, the impact would be calculated as:

$$Impact(€) = Indicator\ (\#) \cdot\ Unitary\ reference\ cost\ (€/\#)$$

Where the indicator, for example in the previous cases, would be the kilometres of bike or bus lane, the square metres of solar panels, or the tons of CO2 emitted.

However, it should be noted that finding the economic value of these unit reference costs is often not an easy task. Furthermore, given the nature of the possible actions or outcomes proposed, which can range from proposals for the implementation of renewable energies to social plans or new legislation, this task is even more difficult.

For these cases where the unit reference cost cannot be obtained, the Option 2, the use of Financial Proxies, is explained below.

II. Option 2: Financial proxies

Financial proxies are variables or indicators used to estimate or infer economic values that cannot be directly measured. They are based on the premise that certain variables are correlated with others that are difficult to quantify, and therefore, they can be used as substitutes or approximate indicators.

These financial proxies are particularly useful in situations where direct data is scarce or difficult to obtain, but there are related variables that can provide useful information.

An example of a financial proxy could be, in the case of an urban road causing noise problems for residents, the cost of installing sound protection barriers, such as acoustic screens, or new glass in buildings would serve as the financial proxy.

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Another example of a more social nature could be a preventive medicine program in elderly care homes. In this case, the financial proxy would be the savings in future treatments that are no longer necessary due to this preventive medicine plan.

There are 5 steps of this stage (NEF, 2008).

a) Identify financial values and proxies
b) Deadweight and displacement
c) Attribution
d) Drop-off
e) Calculating your impact

Next, each of the 5 steps necessary to calculate this impact is explained in detail.

a) Identify financial values and proxies

The subsequent phase involves determining methods for articulating the indicators in monetary terms. The next step is to find ways of expressing the indicators in financial terms. In selecting financial values there is a trade-off between cost, data availability and accuracy.

At this step it has to engage the living labs for data collection, which is missed in the database against the defined outcomes for each field of action. The data which will be unavailable for outcome, it will ask the Railways to give an approximate monetary value (€) against the missing outcome.

Term "Proxy" is used in S-ROI instead of "approximate". Proxies prove highly beneficial as they allow the incorporation of outcomes that lack a direct monetary value. As with defined indicators, stakeholders are the best placed to choose the right values and it is possible to do experiment with different values.

b) Deadweight and displacement

Deadweight is a measure of the amount of outcome that would have happened even if the strategic planning in ToC had not taken place. It is calculated as a percentage. For example, 30% reduction in the need for private motorised mobility even if not providing bike parking because it can be reduced with the integration of public transport. To calculate deadweight, it will do Multi criteria analysis (MCA) from all living labs for getting the solid value in percentage against each indicator.

c) Attribution

Attribution is an assessment of how much of the outcome was caused by the contribution of Railways. Attribution is calculated as a percentage (i.e., the proportion of the outcome that is attributable to living labs). For example, by reducing the car parking will decrease the carbon emission it can't be claimed how much there is reduction in emission value, therefore there is need to determine what share will decrease with that outcome.

d) Drop-off

Drop-off measures the reduction of the outcome after the intervention has been implemented, i.e. the value by which the effect is decreasing over time. For example, if it is increasing the bike-parking space until which year they can serve the demand efficiently.

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Figure 12 shows an example of calculating the outcome if the station will serve as a hub of intermodal mobility.

Outcomes	Indicators	Deadweight	Attribution	Drop-off	Financial proxy	Impact
		%	%	%	€	€
Station as Hub intermodal mobility	Define indicators from database	What would have happened without the outcome?	Who else contributed to the change?	Does the outcome drop off in future years? (annually)	Quantity times financial proxy, less deadweight, displacement and attribution	
Provision of secure (bike / micro-mobility) parking to support multi-modal transportation vehicles		0%	20%	50%	monetized value of multimodal transport vehicles in	
Increase the safety of parking bicycles and micro-mobility services		0%	0%	0%	monetized value of safety	
Reduce time spend during transfer between different means of transport		0%	0%	0%	monetized Value of time	
Degree of functional seamlessness of transition between these services (Multimodal ticketing options and Information of Bike rental facilities at destination station)		0%	0%	0%	Value of multimodal ticketing option.	
Degree of spatial seamlessness of transition between these services (Multimodal ticketing options and Information of Bike rental facilities at destination station)		0%	10%	20%	Value of Information of Bike rental facilities at destination station	
Reduce the need for private motorized mobility		30%	50%	0%	Social marginal road congestion cost	
Provide bike lanes & parking spaces		0%	10%	20%	Cost for providing the car parking	
Reduced car parking spaces		0%	10%	20%	Monetized benefits of more space	
Efficient degree of coordination for functional (e.g. data sharing, ticketing, timetables) and spatial aspects		0%	0%	0%	Monetized value of efficient system	

Figure 12: Example of financial proxies' methodology.

e) Calculation of impact

The impact will be calculated from the following equation for each outcome for each living lab.

$$Impact = [(Financial\ proxy)\ X\ (Outcomes)] - [Deadweight, attribution, drop\ off]$$

Once the impacts of the Outcomes are calculated, they need to be aggregated in order to proceed with the analysis. The process is explained in the following section.

5. Aggregation of costs and benefits (discount rate)

To aggregate the costs and benefits of the Outcomes generated at different points in time, it is necessary to apply a discount factor that allows us to bring future amounts to the present, making them comparable. This involves multiplying the impacts (those generated by unit costs and/or those generated by financial proxies) generated at each moment by a discount factor that indicates how much it values each euro generated at a certain future time point today.

The objective of the social discount rate is to reflect the opportunity cost of the resources used. The form of the discount rate, the functional relationship between the discount factor and time, determines the relative valuation of benefits and costs at different moments over the project's

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evaluation horizon. The most commonly used form is an exponential discount rate, which involves multiplying the amounts generated at each moment by a discount factor equal to

$$D(t) = \frac{1}{(1+r)^t} \quad \text{where:}$$

- r: is the social discount rate
- t: the number of periods that have passed between the present and the generation of these costs or benefits.

For $r > 0$ and $t > 0$, the discount factor is less than 1, implying that society values present amounts more than future amounts because as t increases, the discount factor decreases.

This discount rate can be specific to each country, as demonstrated by the European Commission (EC, 2008). During the development of WP3, specific discount rates can be found if required. However, European guidelines on CBA recommend the use of a generalised discount rate of 3%.

6. SAIT Results

What it obtains from the explained SAIT methodology, and what culminates the process, is the Sustainable Net Present Value of Impacts (SNPV of Impacts), the numerator of our S-ROI indicator quotient. To obtain the SNPV of Impacts, which measures the sum over the entire project's time horizon (T) of the change in the difference between social benefits (Bst) and social costs (Cst) at each time interval (t) discounted to the present based on the discount rate (r). Where Bst and Cst are the impacts calculated previously, considering them as costs or benefits.

This measure results in an interpersonal (among all involved agents) and intertemporal (over the entire lifespan) aggregation of project flows into a single indicator.

To calculate it, the following formula is used:

$$SNPV\ of Impacts = \sum_{t=0}^{T} \frac{\Delta(Bs_t - Cs_t)}{(1+r)^t} \quad \text{where:}$$

- *SNPV* represents the Sustainable Net Present Value
- *T* is the maximum time horizon defined within the outcomes
- Bs_t are the impacts defined as benefits
- Cs_t are the impacts defined as costs
- *r* is the discount rate
- *t* is the time period

Finally, the previous work can be synthesised into a single matrix, called the agent-impact matrix, where each involved agent is detailed in different columns, and the impacts received by each of them are specified in different rows (see Figure 13). In the rightmost column, you can see the sum of the net present value for each of the Solutions considered, while the bottom row displays the sum of the change in welfare experienced by each of the agents.

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			AGENTS				
			Public Administration	Service Manager/Operator	Users	Society	SUMMATION OF IMPACTS
IMPACTS		Investment	M				0,00
		Operation	M	M			0,00
		Maintenance	M	M			0,00
		Users	M	M	M		0,00
	Externalities	Pollution			M	M	0,00
		Climate change			M	M	0,00
		Noise			M	M	0,00
		Landscape			M	M	0,00
		Liberation of public space			M	M	0,00
							Total SNPV
		SUMMATION OF AGENTS	0,00	0,00	0,00	0,00	0,00

Figure 13: Example of the agent-impact matrix for each Solution; M = Monetized Impact (Source: own elaboration).

4.2.2 S-ROI Ratio

The S-ROI (Sustainable Return on Investment) ratio is a metric used to assess the sustainable value or impact generated relative to the investment made in a particular project or initiative. It quantifies the sustainable benefits achieved per unit of investment.

By summing all the values of the SNPV of the agents (Sum of all the columns of the agent-impact matrix) (Williams, 2010) or with the sum of the rows, the total SNPV of the impacts is obtained. With this, together with the value of the investment of the Solution, the S-ROI ratio of the Solution is obtained. Subsequently, this will allow for the selection of the best alternative or Solution for the action (Maldonado, 2016).

$$S - ROI = \frac{\Sigma\ SNPV\ of\ Impacts}{Value\ of\ Investment\ for\ each\ Solution}$$

For instance, if the S-ROI ratio is calculated as 4.5:1, it means that for every unit of investment (e.g., 1 €), the project generates a sustainable benefit equivalent to 4.5 units (e.g., 4.50 €). In other words, the project generates 4.50 € in social value for every 1 € invested.

This ratio provides valuable insight into the efficiency and effectiveness of sustainable investments, helping stakeholders understand the sustainable impact achieved relative to the resources expended. A higher S-ROI ratio indicates greater sustainable value generated per unit of investment, making it a key indicator for decision-making and resource allocation in sustainable projects and initiatives.

4.2.3 Sensitivity analysis

The sensitivity analysis in Sustainable Return on Investment (S-ROI) is an important tool that allows understanding how certain key variables affect the final outcome of the analysis. This type of analysis helps identify the factors that have the greatest impact on sustainable investment return and understand how conclusions may change under different scenarios.

Here are some steps to perform a sensitivity analysis in S-ROI:

1. **Identification of key variables:** Identify the variables that can significantly influence the sustainable investment return. These may include financial, social, and environmental factors. An example could be the values of Time (VoT), since they are very subjective and depend greatly on the perception of each user.
2. **Determination of plausible ranges:** defining plausible ranges or extreme values that these variables could take. This involves identifying the range within which each variable could vary and how these variations could affect the S-ROI outcome.
3. **Impact on S-ROI outcome:** evaluate how changes in each key variable affect the final outcome of the S-ROI analysis. This can be done by adjusting each variable individually within its defined range and observing how the analysis outcome changes.
4. **Identification of risks and opportunities:** use the results of the sensitivity analysis to identify potential risks and opportunities associated with the project or investment. This can help make more informed decisions and develop strategies to mitigate risks and capitalise on opportunities.

In summary, sensitivity analysis in S-ROI is a valuable tool for assessing the robustness of analysis results and better understanding how different variables can influence sustainable investment return. It helps decision-makers understand the risks and opportunities associated with the project or investment and make more informed and strategic decisions.

4.2.4 Methodology streamlining

The methodology presented allows for the precise quantification, with scientific robustness, of the analysis of the impacts of the proposed Solutions on the TOC. However, this methodology has a drawback, which is that it needs to be fed with a lot of data, which can sometimes be difficult to obtain in projects.

With the aim of guaranteeing the use of the presented methodology, a simplification of it is presented below. The intension behind introducing a simplifying approach like ToC is to address situations where obtaining comprehensive data for the impact assessment may cause significant challenges. Therefore, this simplified methodology offers a practical solution for addressing challenges associated with data availability and resource constraints. Because the data is collected from the stakeholders in ideation workshops in D3.1. The maximum data will be asked from the stakeholders in ideation workshop, the more the data is collected the stronger results will be achieved, but there is minimum range of data is also defined in the methodology from which results can be driven. Therefore, the adoption of simplified methodology is because of availability of data. Sensitivity analysis will also be done in this simplified methodology regardless of availability of data. The simplified methodology streamlines the process, it may not capture all nuances and intricacies compared to the more comprehensive approach. Therefore, it's essential to consider the limitations of this simplified method when interpreting the results.

a) Theoretical approach of the simplified methodology

The simplified methodology would consist of two steps:

1. **Identification of costs and benefits.**
    - Identify all costs associated with implementing the proposed Solutions, including direct costs such as materials or labour.
    - Identify potential benefits resulting from the implementation of the Solutions, such as increased efficiency, reduced downtime, or increased revenue.
    - Quantify both the costs and benefits as accurately as possible, considering available data and estimations. For this purpose, you can use either Reference Costs (Option 1 from the original methodology) or Financial Proxies (Option 2).
2. **Quantification of the S-ROI ratio.**
    - Calculate the S-ROI (Simplified Return on Investment) ratio by dividing the total benefits by the total costs incurred.
    - The formula for S-ROI is:

$$S - ROI = \frac{\Sigma\ Benefits}{\Sigma\ Costs}$$

    - Evaluate the resulting ratio to determine the overall efficiency and effectiveness of the proposed Solutions implementation. A higher S-ROI indicates a more favourable return on investment, while a lower ratio suggests less efficiency in relation to costs.

Therefore, this simplified methodology, compared to the original, dispenses with:

- Discount ratio: indicates how much it values each euro generated at a certain future time point today.
- Agent-impact matrix and characterization of the agents.
- Sensitivity analysis.

Please note that while this simplified methodology streamlines the process, it may not capture all nuances and intricacies compared to the more comprehensive approach. Therefore, it's essential to consider the limitations of this simplified method when interpreting the results.

b) Qualitative example

The chosen example is "Implementation of solar panels in big parking lots." Below is the qualitative procedure for calculating the impact following the steps outlined in the previous section presenting the simplified methodology.

Step 1: Identification of Costs and Benefits

- Costs: these include expenses related to the price of the solar panels.

$$Cost(€) = Solar\ panels\ surface\ (m^2) \cdot\ Cost\ of\ solar\ panels\ per\ m^2 (€/m^2)$$

- Benefits: in this case environmental benefits: amount of reduction of kWh produced with non-renewable energies. In this case, it would be assumed that the kWh generated by the solar panels are the ones replaced or reduced from those produced by non-renewable energies.

$$Reduction\ of\ kWh\ non - renewable\ sources (kWh) = Solar\ panels\ surface\ (m^2) \cdot\ Solar\ panels\ production\ per\ m^2 (kWh/m^2)$$

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Equivalent in sustainability scale of this saving in production with non-renewable energies (tCO2eq), and economic benefit.

$$Reduction\ of\ pollutants\ (tCO_2eq) = Reduction\ of\ kWh\ non-renewable\ sources(kWh) \cdot Pollutant\ ratio(tCO_2eq/kWh)$$

$$Benefit\ (€) = Reduction\ of\ pollutants\ (tCO_2eq) \cdot\ Economic\ impact(€/tCO_2eq)$$

Step 2: Quantification of the S-ROI Ratio

Using the simplified S-ROI formula:

$$S-ROI = \frac{\Sigma\ Benefits}{\Sigma\ Costs}$$

If we assume, for example, that the costs are €500,000 and the benefits are €700,000.

$$S-ROI = \frac{700.000\ €}{500.000\ €} = 1.4$$

An S-ROI ratio of 1.4 indicates that for every euro invested in the solar panels, there is a return of €1.40. This suggests a positive return on investment and indicates that the project is sustainably viable.

Once the methodology and the example have been presented, it should be mentioned that this is the simplest way to implement the S-ROI methodology. In this approach, only costs, benefits, and the ratio are calculated. Even though it is a simplified method, it still requires data input, although significantly less than the original methodology.

4.3 Stage 3: Prioritisation of Actions

In order to prioritise the solutions for each action, it has been decided to use, on the one hand, a multicriteria analysis (MCA) evaluation and decision method to select one of them. And on the other hand, S-ROI methodology. The solutions for each action have been proposed in the ToC, and they are characterised as the Solutions. It should be noted that the final results of the ToC are not yet available, so some points of this methodology are not final.

The goal is to obtain two parallel analyses from two different perspectives, explained in the previous section:

- Multicriteria analysis (MCA)
- Sustainable return on investment (S-ROI)

Subsequently, both approaches are outlined.

4.3.1 Methods and tools: S-ROI

The objective of the S-ROI methodology is to obtain an objective indicator of the net contribution or overall benefit of each of the solutions to subsequently choose the best solution (in our case the Solution from the previous ToC methodology).

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The goal is to identify those Solutions that achieve a higher performance in terms of sustainability, and therefore, those Solutions or proposed solutions with a higher S-ROI ratio (Figure 14).

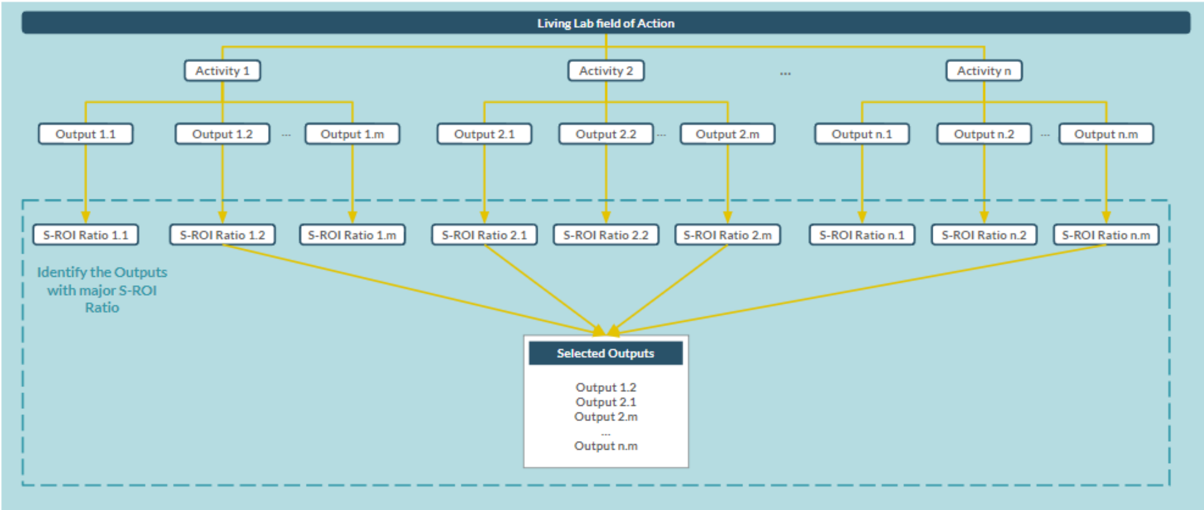

Figure 14: Method for selecting the best alternative (Solution) according to S-ROI (Source: own elaboration).

Once the Solutions with higher yields, that is, with higher S-ROI coefficients, have been identified through the results of the MCA for these same Solutions, the actions that best align with the objectives of the Living Labs can be chosen.

4.3.2 Methods and tools: MCA

The Analytic Hierarchy Process (AHP) has been chosen among the various possible methods to perform the multi-criteria analysis. The method consists of formalising the understanding of complex problems, considering various criteria and conditions, through the construction of a conceptual scheme or hierarchical model based on quantitative or qualitative assessments. The purpose of the model is to allow the decision-maker to structure the multi-criteria problem in a clear and visual way, through the construction of a three-level model: objective, criteria and sub-criteria or indicators and alternatives.

The method starts with the identification of the main objective and the determination of the criteria and sub-criteria, applied to the alternatives. The hierarchy represents the relationships between the following elements (see Figure 15):

- **Level 1:** Primary Objective. The aim would be to select the solutions with the greatest potential in each of the actions.
- **Level 2:** Criteria and sub-criteria. The first ones could be Infrastructure, Environmental, Social, Financial, Accessibility, Technology and Safety; while the sub-criteria would be specific KPIs within each criterion.
- **Level 3:** The different alternatives or viable solutions would be proposed for each action.

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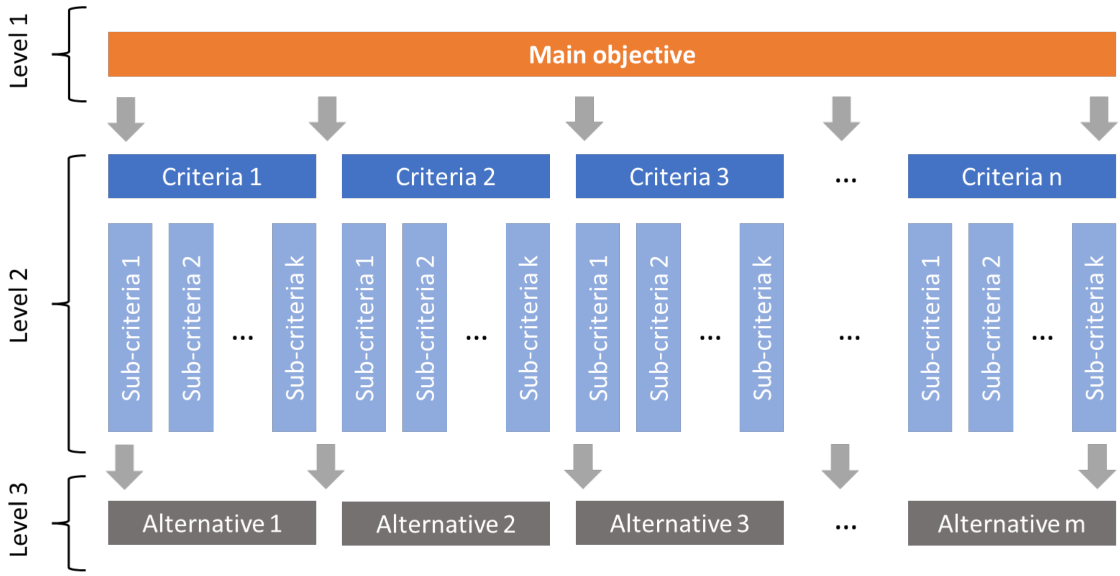

Figure 15: Conceptual diagram or hierarchical model of the Hierarchical Analytical Process (AHP).

The steps to follow according to the AHP are the following:

1. **Adapt the conceptual scheme** or hierarchical model to the problem posed. It consists of identifying and determining the main objective (level 1), the set of criteria or sub-criteria (level 2) and the different feasible alternatives (level 3).
2. **Comparison of the different criteria identified with each other**. The comparison is made in pairs between the elements, which are assigned different numerical values obtained qualitatively or quantitatively and which must be duly justified. To carry out these qualitative comparisons, the rating scale proposed by Saaty (creator of the method) is used, numerical, with values from 1 to 5. Below is a table that includes the ratings and their interpretation:

Evaluation	Definition	Interpretation
1	Equally important	The two elements compared are equally important with respect to the achievement of the main objective
2	Moderate importance	One element is moderately more important than the other
3	High importance	One element is much more important than the other
4	Very high importance	One element is much more important than the other and is clearly demonstrated in practice
5	Absolutely high importance	It is clearly demonstrated that one element is absolutely more important than the other. It is the maximum possible rating.

Table 1: Evaluation table of the Hierarchical Analytical Process.

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If necessary, the intermediate values between the ratings can be used, in the event that a finer rating can be made between two elements.

If the comparison is carried out quantitatively, the score in question is obtained for each case and it must be transferred to the Saaty scale, from 1 to 5, proportionally.

As a result of these one-to-one comparisons between criteria, the comparison matrix for pairs of criteria is obtained, from which the weight represented by each of them is finally obtained, information that is stored to the vector of criteria weights.

1. **Comparison of the alternatives, for each evaluation criterion**. For each of the identified criteria, a comparison is made, one by one, between the different feasible alternatives. This assessment can be qualitative, based on the assessment table presented in the previous section, or quantitative. In other words, for each criterion a comparison matrix of alternatives is constructed, from which a vector of alternative weights is obtained.
2. **Determination of global weights and selection of the alternative**. With the weights obtained from each criterion (level 2) and the weights that the alternatives have for each criterion (level 3), the global weights of each alternative are determined. The selected alternative is the one with the highest score.

Below is a schematic summary of the steps to be described:

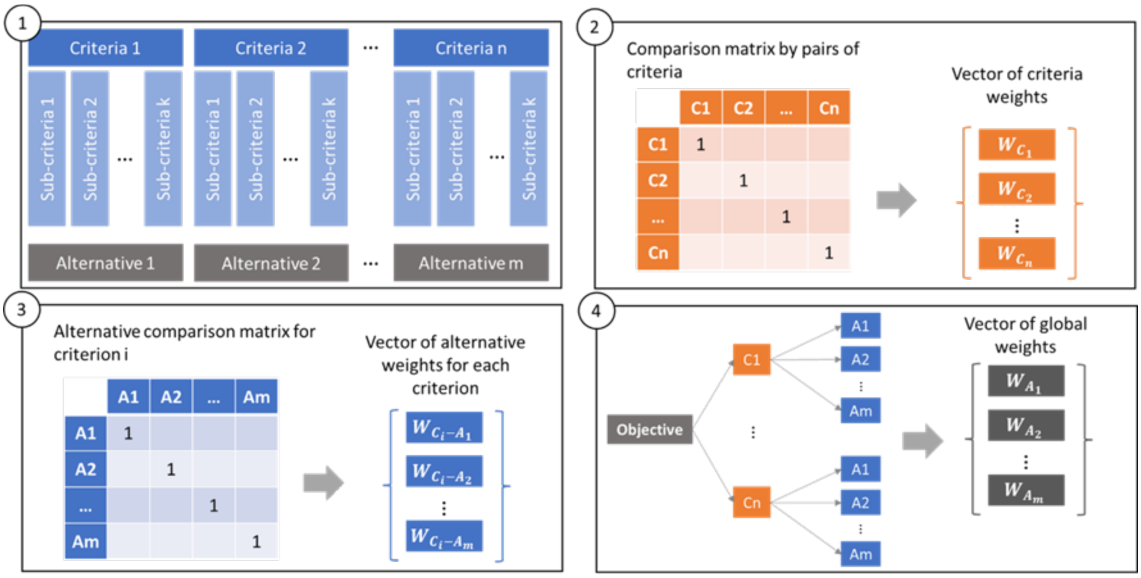

Figure 16: Synthesis of steps to follow according to the AHP methodology.

Adaptation of the conceptual scheme

In order to evaluate which solution has the most impact for each action, the set of alternatives/solutions considered are based on the different solutions explained in the TOC (remember that it has not yet been completed).

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As for the evaluation criteria (not final), a total of 7 criteria have been identified:

Criteria	Description
Infrastructure	Evaluate the infrastructure to be implemented according to the action.
Environmental	Assess the environmental impact of the project, including greenhouse gas emissions, land use and potential impacts on local ecosystems. Consider sustainability objectives and prioritize environmentally friendly energy sources and technologies.
Social	Ensure that diversity, inclusion and affordability are promoted by providing a mix of service options that suit people of different income levels, backgrounds and abilities.
Financial	Conduct a comprehensive cost-benefit analysis to assess economic viability. Consider investment costs, operating expenses, revenue streams and the potential return on investment over its lifetime.
Accessibility	Ensure that the hub is easily accessible for each action. Adequate infrastructure must be in place to facilitate smooth circulation.
Technology	Evaluate the maturity and reliability of the technologies involved in the action. Consider scalability and compatibility with future innovations.
Safety	Safety of property, facilities, personnel and citizens is paramount. Choose a location with low crime rates and adequate security measures.

Table 2: ***Defined criteria (provisional).***

A set of indicators will be identified for each criterion for each action. Some examples are given below:

Criteria	KPI	Description
Infrastructure	Number of e-vehicles charging points	Number of recharging points for electric vehicles will be built new
Environmental	Reduction in CO2	How many kg of CO2 will be reduced with this solution
Social	Amount of socially inclusive projects/interventions taking place in and around the stations	How many social inclusion projects/interventions will be carried out in this solution.
Financial	Amount of financial resources allocated to public-private partnership projects connected with the railway station and surrounding area development	Total investment to be made with this solution.
Accessibility	Distance to surrounding public transport stops	How many meters there are between public transport stops
Technology	Usage of digital twin methods	If Digital Twins will be used in this solution
Safety	Extent of public spaces provided around stations	If public spaces around stations were to be extended in the implementation of the solution.

Table 3: Indicators defined for each criterion (example).

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Comparison of the criteria

As indicated in the general description of the AHP methodology, the comparison of the criteria is done qualitatively according to the rating scale presented. Therefore, for each particular case, it is crucial to identify and consider this set of conditions in order to adjust the evaluation of the criteria in the most appropriate way possible. Once the comparison matrix has been obtained, it must be normalized to facilitate the interpretation of the criteria weights. These will have values between 0 and 1, so that the results are easier to interpret in order to know which criterion has a higher weight and to be able to compare it with the other criteria.

An example of the criteria pairwise comparison matrix, with the criteria defined above, is shown below.

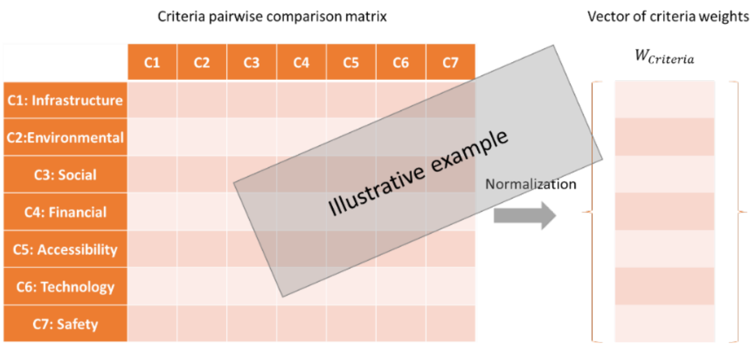

Figure 17: Example of criteria pairwise comparison matrix and corresponding vector of criteria weights.

Normalization is performed as follows:

- Sum the columns of the criteria pairwise comparison matrix (*C*).
- Create the normalized criteria pairwise comparison matrix (CN).
- Where the values of each cell are calculated as follows:
  - $CN_{ij} = \frac{C_{ij}}{\sum_{j=1}^{7} C_j}$, where *i* are the rows and *j* are the columns.
- Calculate the weight of the criterion:
  - $W_{criteria_i} = \frac{\sum_{i=1}^{7} CN_i}{N}$, where *N* is the total number of criteria.

Comparison of the alternatives

The comparisons between alternatives for each criterion are determined by the ratings obtained from the different indicators. Proceed as follows:

- The comparison of the indicators is carried out qualitatively with the same procedure as for the criteria. Creation of the comparison matrix by pairs of sub-criteria for criterion i, normalization of this matrix and obtaining the vector of weights of the sub-criteria for criterion *i*.

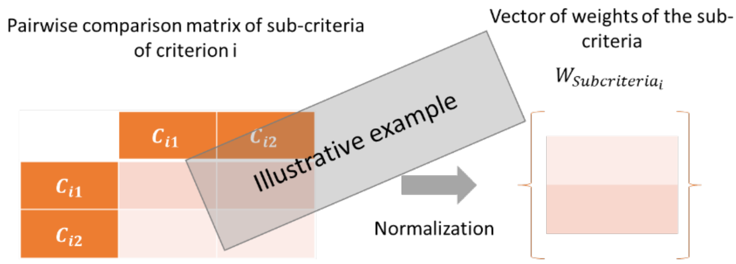

Figure 18: Example of a pairwise comparison matrix of sub-criteria of a criterion and the corresponding vector of sub-criteria weights of the criterion.

- Quantitative or qualitative evaluation, as appropriate, of the alternatives for each indicator/sub-criterion defined on the basis of the indicators (KPIs) evaluated for each sub-criterion.

Data KPI	Metrics	A1	A2	A3	A4	A5	A6	A7	A8	A9

Figure 19*:* Example of reference data collection table.

	A1	A2	A3	A4	A5	A6	A7	A8	A9
C_{i1}									
C_{i2}									

Figure 20: Example of a table for the evaluation of each sub-criterion for each alternative.

- Sum product of the scores or ratings obtained by the indicators/sub-criteria for each alternative (Figure 18) by the vector of weights for each indicator/sub-criterion (Figure 20Figure 21).

	A1	A2	A3	A4	A5	A6	A7	A8	A9
C_{51}	5	5	1	5	5	5	5	1	1
C_{52}	4	3	3	3	4	3	2	2	4
Total sum	4,25	3,50	2,50	3,50	4,25	3,50	2,74	1,75	3,26

Figure 21: Example of the result of the sum product between the scores and weights of the sub-criteria for each alternative.

- Now it proceeds to obtain the alternative comparison matrices. The purpose of the matrices is to be able to compare the alternatives two by two according to the criterion, as was done in

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the criteria matrix. These comparison matrices are prepared from the table in Figure 21 with the following procedure:

- $MCA_{ij} = \frac{\sum_{s=1}^{n} C_{ksi}}{\sum_{s=1}^{n} C_{ksj}}$, where *i* and *j* are the alternatives, *k* is the criterion, *n* the number of sub-criteria. Once an *i* (row) is set, the procedure is done for each *j* (column).

- Once the comparison matrices have been obtained, the same procedure is applied as for the criteria comparison matrix. Therefore, the matrix is normalized and the vectors of weights of alternatives are calculated for each criterion.

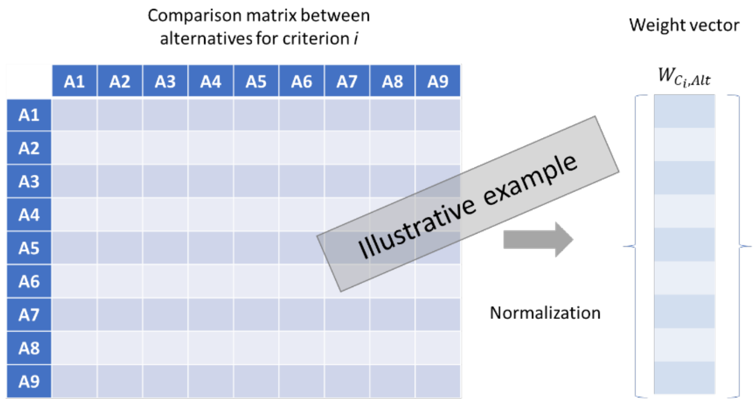

Figure 22: Example of the comparison matrix and the resulting vector of weights for each criterion.

- The set of vectors of alternative weights is used to form the joint matrix with the vectors of alternative weights for each criterion (in which each row corresponds to one of the vectors mentioned above).

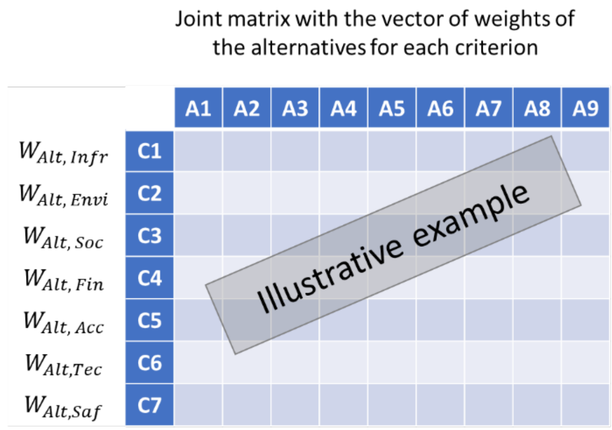

Figure 23: Example of the joint matrix with the vector of weights of the alternatives for each criterion.

As in the previous case, these valuations are also subject to variations depending on the particular case study.

<u>Determination of global weights and selection of the alternative</u>

Once the vector of weights of the criteria and the joint matrix with the vectors of weights of the alternatives for each criterion are obtained, it is possible to obtain the vector of global weights.

This vector is characterized by the fact that in each component it contains, as for, the weight or result score obtained by each of the alternatives.

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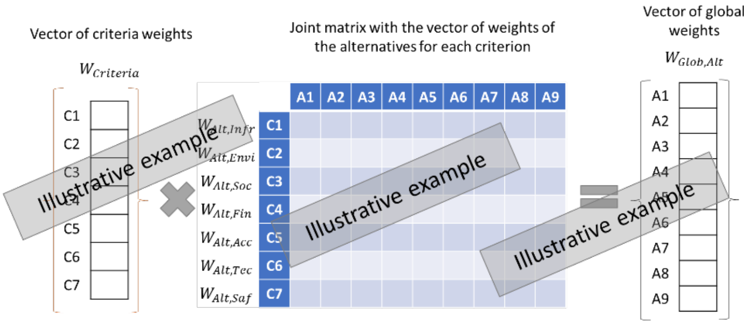

Figure 24: Obtaining the vector of global weights.

So, the selected alternative will be the one that gets the highest score compared to the others.

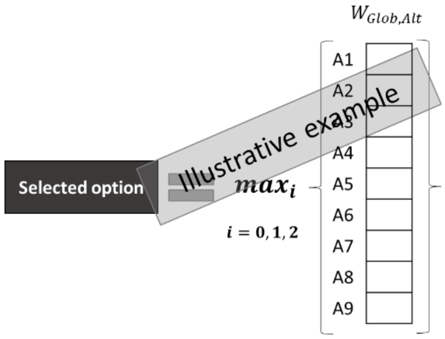

Figure 25: Example of obtaining the solution with the best impact.

4.3.3 Result

The outcome of a multicriteria analysis (MCA) typically involves the identification of the most suitable option or decision alternative based on the evaluation of multiple criteria or objectives.

Here's a breakdown of the possible outcomes of an MCA:

- Preferred Alternative Identification
- Ranking of Alternatives
- Sensitivity Analysis
- Recommendations for Decision-Making

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5 Tool setup and transfer of the knowledge

Once the methodology of both S-ROI and MCA has been presented, it is necessary to develop a tool that allows the use of these methodologies by the involved agents. The objective of this section is to present the bases on which said tool will be based.

The tool will be designed in Microsoft Excel. It will consist of three parts:

1. **S-ROI Methodology Excel:** All necessary steps for carrying out the S-ROI methodology presented in this report will be provided, as well as the visualisation of the results.
2. **MCA Methodology Excel:** All necessary steps for carrying out the MCA methodology presented in this report will be provided, as well as the results of the MCA process.
3. **Global Results Analysis:** This section will allow the visualisation of the results of both methodologies, which is necessary for decision-making regarding the prioritisation of solution or proposed solution.

Each of the three mentioned parts will be individual Excel files, since the MCA will consist of several tabs, one for each criterion, and creating a single Excel file would hinder its operation and understanding.

Below, each of these parts is explained in greater detail.

5.1 S-ROI Methodology Excel

This part of the Excel focused on the S-ROI analysis will consist of three tabs:

1. **Reference Unitary Costs and Financial Proxies Tab:** In this tab, users will be presented with all the Reference Unitary Costs and Financial Proxies collected during the development of the Project, specifically in WP3. The aim is to provide greater traceability to the tool and allow users to see where all the values used during the analysis come from.
2. **Impacts calculation:** the main objective of this window is to calculate the impacts by introducing indicators and the Reference Unitary Costs and Financial Proxies. The user will be able to enter the time horizon of the impact, as well as the affected agent.

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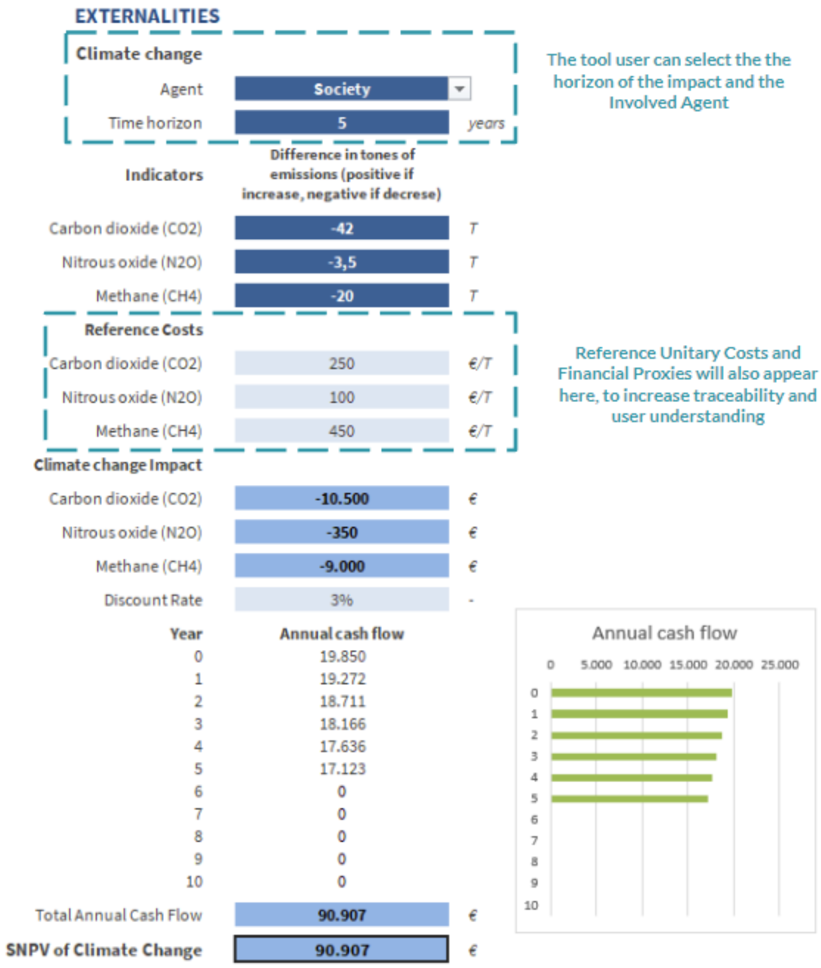

Figure 26: Proposed scheme for Impacts Calculation Tab.

In Figure 26, you can also see how the annual cash flow and the total NPV of the Impact appear. The objective is to obtain a section similar to the one shown in the figure for each impact, in order to obtain the total NPV of the Solution.

3. **S-ROI Results:** in this last tab, the following will be obtained:

    - The matrix of impacted agents as presented earlier.
    - The S-ROI coefficient of the Solution.
    - Possibility to perform sensitivity analysis for certain proposed parameters.

5.2 MCA Methodology Excel

In the tool to apply the MCA methodology, 3 types of inputs (the inputs will be set by the developers of the methodology based on the information obtained from the workshops, since it is qualitative information) are needed:

- Putting importance between pairs of criteria (1 equally important and 5 1 is much more important than the other).
- Putting the importance between pairs of KPIs for each criterion.
- Collect the data for each KPI and rescale it to a scale between 0 and 5 for comparison.

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In the same Excel there will be different sheets where the corresponding cells will be marked with a different colour where the inputs will be. The Excel will be composed of a main sheet where the definition of the criteria, the comparisons between criteria and the summary of the comparisons of each solution per criterion will be. Then there will be as many sheets as there are criteria to perform the hierarchical analysis of each criterion and finally the final sheet, where the solutions will be listed in order, from most to least important when it comes to being implemented.

5.3 Global Results Analysis

In this Excel, the two Excels, the S-ROI and the MCA, will be related, where the results will be. From the results, they will be analysed together to draw the final results, conclusions and recommendations to be followed to implement the corresponding solutions.

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6 Discussion and further implications

Methodology for the efficient planning and transformation of railways stations as new urban vital centres, integrating SCP methodology, S-ROI framework.

As outcomes, the integration of S-ROI calculation in the cost-benefit analysis aims at:

- Better understanding of how sustainability and the financial area relate.
- Greater awareness of sustainability issues as an integral part of the business operation.
- Company participants will feel better prepared for upcoming sustainability standards and regulations.
- Railway companies will start to integrate S-ROI methodologies in their internal CBA for their future projects, as they will see the benefits of such a calculation and will also have an impact on their collaboration with local institutions.

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7 Conclusion

To put it briefly, the goal of this deliverable is to create a methodological framework for assessing the new station model. The methodology's goal is to calculate the Sustainable Return on Investment (S-ROI) in addition to economic costs and benefits (CBA). As a result, this developed methodology will assess not only the economic CBA but also but also assess the effects on the urban ecosystem. To perform the cost-benefit analysis (CBA*), "Sistema d'Avaluació d'Inversions en Transport"* (SAIT) will be used. To fully evaluate the model's impact further three interrelated methodologies are formulated: S-ROI, Multicriteria Analysis (MCA), and Theory of Change (ToC). The ToC, which outlines activities, solutions, and impacts across multiple sectors of activity, forms the basis for S-ROI and MCA. Together with MCA results, the S-ROI technique seeks to objectively quantify the net contribution of outputs to choose the best solutions that address social, environmental, and economic factors.

This deliverable D2.2 has designed the methodology, that will be implemented in WP3's operational phase and assessed in WP4 across all living labs. In the end, the impact assessment technique that has been created will make it easier to conduct in-depth investigations at the living lab level in WP3 and WP4, which will allow for the development of innovative solutions that address social, environmental, and economic concerns.

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