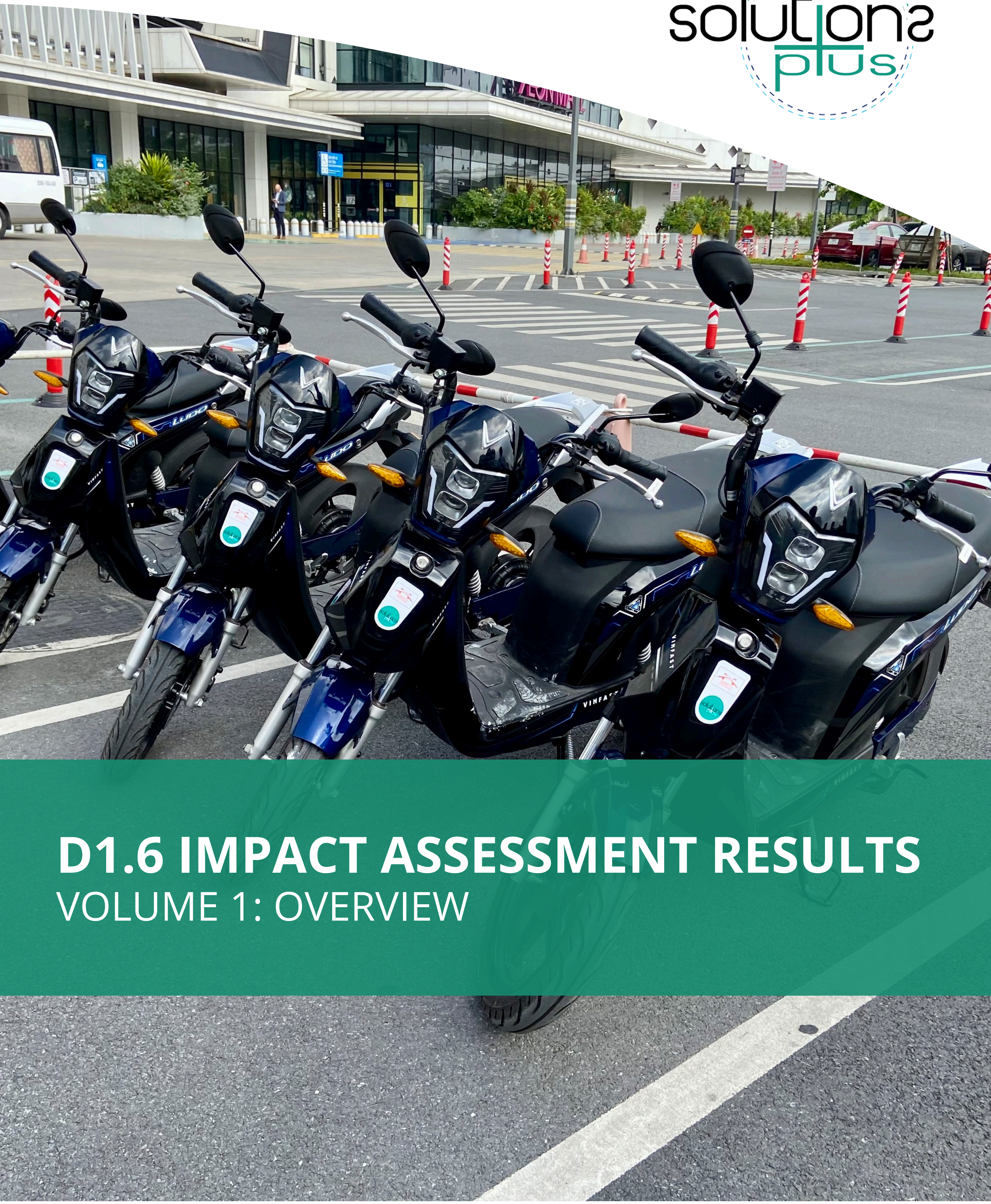


D1.6 IMPACT ASSESSMENT RESULTS

VOLUME 1: OVERVIEW

This project has received funding from the European Union Horizon 2020 research and innovation Programme under grant agreement no. 875041

PROJECT PARTNERS

ABOUT

This brochure has been prepared for the project SOLUTIONSplus. The project has received funding from the European Union's Horizon 2020 research and innovation programme under the grant agreement no. 875041

TITLE

SOLUTIONSplus Impact Assessment Results

AUTHORS

George Panagakos (DTU), Subash Dhar (UNEP), Bachtijar Ashari (TNO), Naressa Saripada (CAA), Mirko Goletz (DLR), Eetu Wallius (VTT), Stefan Werland (WI), Alois Steiner (V2C2), Xianli Zhu (UNEP)

REVIEWERS

Talat Munshi (UNEP), Michael Barfod (DTU)

DISCLAIMER

LAYOUT

Yasin Imran Rony, WI

PICTURES

All the pictures are provided by the SOL+ partners

June, 2024

JUNE 2024

DOCUMENT IDENTIFICATION			
STATUS	Final	DUE DATE	30 April 2024
VERSION	v2.0	SUBMISSION DATE	25 June 2024

DELIVERABLE NUMBER	D1.6 – Volume 1
DELIVERABLE NAME	Impact assessment results - Volume 1: Overview
WORK PACKAGE NUMBER	WP1
DELIVERY DUE DATE	30 April 2024
ACTUAL DATE OF SUBMISSION	25 June 2024 (Version v1.0 was submitted on 3 May 2024)
DISSEMINATION LEVEL	PU
LEAD BENEFICIARY	DTU
BENEFICIARIES	DLR, FIER, IDIADA, TNO, UEMI, UITP, V2C2, VTT, WI
RESPONSIBLE SCIENTIST / ADMINISTRATOR	George Panagakos (DTU), Subash Dhar (UNEP), Bachtijar Ashari (TNO), Naressa Saripada (CAA), Mirko Goletz (DLR), Eetu Wallius (VTT), Stefan Werland (WI), Alois Steiner (V2C2), Xianli Zhu (UNEP)
ESTIMATED EFFORT (PERSON-MONTH)	
INTERNAL REVIEWER	Talat Munshi (UNEP), Michael Barfod (DTU)

This document is issued within the frame and for the purpose of the SOLUTIONSplus project. This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 875041. The opinions expressed and arguments employed herein do not necessarily reflect the official views of the European Commission.

(*) Dissemination level: PU: Public, fully open, e.g. web; CO: Confidential, restricted under conditions set out in Model Grant Agreement; CI: Classified, Int = Internal Working Document, information as referred to in Commission Decision 2001/844/EC.

EXECUTIVE SUMMARY

GENERAL

This report presents the work performed under Task 1.3 (Impact assessment, data collection and evaluation) of WP1 (Toolbox and evaluation) of the SOLUTIONSplus project.

Due to the long duration of the project, it was decided in May 2021 to submit an interim report (D1.6 – Part A) describing the impact assessment methodology to be followed and the early assessment activities of the project. This interim report is now obsolete as its contents have been incorporated in the present deliverable.

The general objective of Task 1.3 is to support the demonstration actions of the project by providing comprehensive impact assessments and evaluations. There are two distinct objects of the assessment activity:

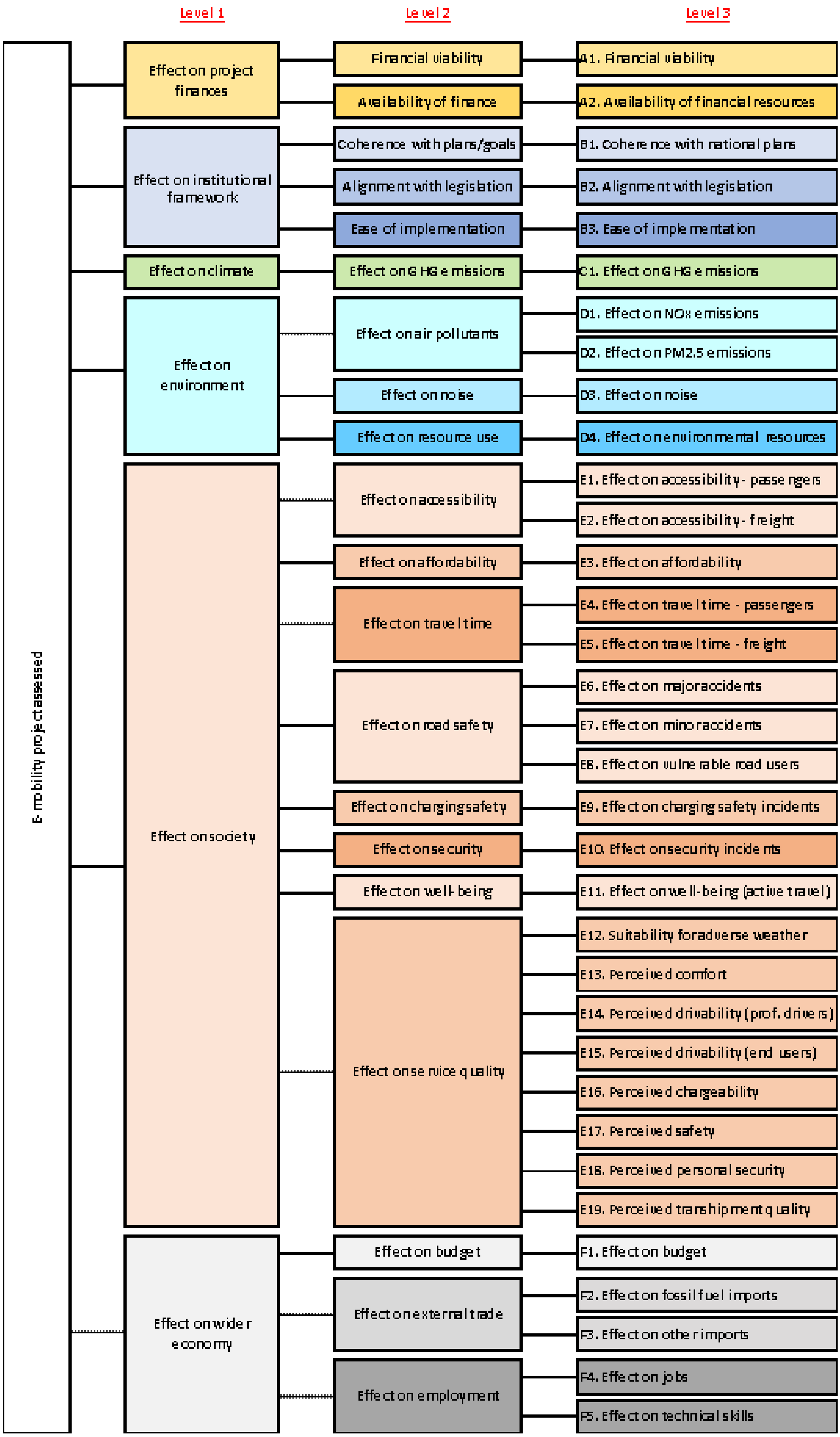
- the city-specific demonstration projects that were planned together with the local stakeholders prior to the commencement of the project, which will be assessed both ex ante and ex post, and
- the city-specific scaled-up projects that will be designed together with the local stakeholders based on the demonstration results, and which will be implemented after the completion of SOLUTIONSplus.

A combination of financial cost-benefit analysis (CBA) with multi-criteria decision analysis (MCDA) techniques was selected to address the need for designing robust bankable scaled-up projects on one hand, while covering a wide range of difficult-to-monetise aspects on the other. This is particularly relevant when covering a range of developing countries around the world, where difficulties in obtaining homogeneous data are not unusual.

A list of 34 KPIs (Level 3), grouped in six families (Level 1), was deployed to cover all perspectives entering the impact assessment task (see figure below). Relative weights were solicited from the local stakeholders to capture the city-specific priorities and values. Furthermore, for cities with multiple demo components, as is the case of Kathmandu, a set of value functions, agreed with the local stakeholders, is used to transform KPI values into uniform star-values (from 1 to 5), which, when combined with the corresponding weights, can result in an overall rating that can be used for comparing alternative scaled-up projects.

The 10 volumes covering one demo city each accompany this document; all together comprise Deliverable D1.6 (Impact assessment results).
The impact assessment task, as implemented in each project city, is described in detail in the respective volume as follows:

Volume 2: Hanoi
Volume 3: Pasig
Volume 4: Kathmandu
Volume 5: Kigali
Volume 6: Dar es Salaam
Volume 7: Quito
Volume 8: Montevideo
Volume 9: Madrid
Volume 10: Hamburg
Volume 11: Nanjing


Level 1
Level 2
Level 3
E-mobility project assessed
Effect on project finances
Financial viability
A1. Financial viability
Availability of finance
A2. Availability of financial resources
Effect on institutional framework
Coherence with plans/goals
B1. Coherence with national plans
Alignment with legislation
B2. Alignment with legislation
Ease of implementation
B3. Ease of implementation
Effect on climate
Effect on GHG emissions
C1. Effect on GHG emissions
Effect on environment
Effect on air pollutants
D1. Effect on NOx emissions
D2. Effect on PM2.5 emissions
Effect on noise
D3. Effect on noise
Effect on resource use
D4. Effect on environmental resources
Effect on society
Effect on accessibility
E1. Effect on accessibility - passengers
E2. Effect on accessibility - freight
Effect on affordability
E3. Effect on affordability
Effect on travel time
E4. Effect on travel time - passengers
E5. Effect on travel time - freight
Effect on road safety
E6. Effect on major accidents
E7. Effect on minor accidents
E8. Effect on vulnerable road users
Effect on charging safety
E9. Effect on charging safety incidents
Effect on security
E10. Effect on security incidents
Effect on well-being
E11. Effect on well-being (active travel)
Effect on service quality
E12. Suitability for adverse weather
E13. Perceived comfort
E14. Perceived drivability (prof. drivers)
E15. Perceived drivability (end users)
E16. Perceived chargeability
E17. Perceived safety
E18. Perceived personal security
E19. Perceived transhipment quality
Effect on wider economy
Effect on budget
F1. Effect on budget
Effect on external trade
F2. Effect on fossil fuel imports
F3. Effect on other imports
Effect on employment
F4. Effect on jobs
F5. Effect on technical skills

The executive summaries of these volumes are reproduced here in Section 3. The remainder of this summary will be devoted to the findings of the horizontal comparisons of Section 4 and an assessment of the methodology itself.

USER NEEDS

When comparing the results of the online survey on user needs across the nine demonstration cities (the Nanjing information was not available at the time of drafting the relevant section), some notable differences were observed suggesting that the role of e-mobility is perceived differently depending on the context of the respective city.
The horizontal comparison of user needs shows that indeed external indicators such as traffic and pollution have an impact on the targeted city aims for e-mobility, especially for extreme values (e.g., the high values of the traffic and pollution indices for Pasig and Kathmandu when compared to the low values for Hamburg). This is an important finding for public policy and practice. Accordingly, a successful transition towards e-mobility requires the identification of both pressing challenges that need to be addressed as well as suitable e-mobility solutions that can provide a remedy. Following, the expected benefits of these e-mobility solutions to address relevant problems in local context need to be communicated effectively to create awareness and increase the overall acceptance of e-mobility.

PASSENGER EVS

The pilots under the SOLUTIONSplus project are mostly paratransit electric vehicles (EVs), an essential transport solution in developing and emerging countries, where a large section of the population depends on these modes of transport for their daily travel. Therefore, most countries are testing out electric vehicles as paratransit mobility options, and the local priorities are also set around getting the project viable and having appropriate institutional frameworks to ensure scaled-up projects.
As most of these initiatives will be run by private operators, it is important that they are financially viable, and most SOLUTIONSplus pilot operations have shown that these are good options financially. The only option with a negative IRR was the Katmandu shuttle van, where the expected passengers were not enough to make the option viable, albeit when compared to the existing option (an open-type electric shuttle van), it exhibits a better CER. Furthermore, converting an old diesel bus into an electric bus can be commercially viable only if significant scale economies can be achieved.
Moving to electric vehicles from ICE vehicles is expected to deliver significant GHG mitigation and benefits in abating air pollution when they are replacing vehicles that are running on fossil fuels. However, when the intervention involved replacing an existing electric vehicle such as a Safa Tempo in Kathmandu the environmental benefits were not registered.

Electric vehicles cost more upfront but are more lucrative in the long term and offer considerable financial and environmental advantages. Most countries are in the process of creating an enabling environment where electric mobility initiatives like the ones proposed here can incubate. It is imperative that these processes continue leading to:

- a proper policy and institutional environment
- the establishment of the necessary charging infrastructure
- the adoption of enabling regulations for local manufacturing (technical

standards, licensing, etc.) that ensure the construction and deployment of safe and robust vehicles
- educating drivers and users to promote e-vehicles as last-mile connections.

FREIGHT EVS

Light electric freight vehicles (LEFVs) prove a popular solution for last-mile urban deliveries, particularly in developing countries such as those of the SOLUTIONSplus project, due to their flexibility, small dimensions and low investment requirements. All vehicles tested exhibit a healthy return on investment, meaning that no financial support is required for their promotion. However, the lighter vehicles such as the e-bikes of Dar es Salaam and the e-cargo bikes of the Latin American cities appear very sensitive to demand forecasts.

Conversions of existing vehicles are generally profitable albeit at lower return rates. In general, however, the old fossil-fuel-driven solutions are also profitable depriving operators of running vehicles from sufficient motivation to convert. As such, conversions at scale can be expected only at the end of the useful lives of existing vehicles.

A well-functioning distribution network (probably supported by a digital management scheme) and integration services (exploiting the consolidation possibilities of e-cargo bikes) are necessary for the efficient operation of LEFVs, leading towards collaborative business models according to the ‘broader EV uptake’ approach (ITF, 2023).

Furthermore, and in order to deploy them effectively, cities need proper planning for infrastructure (both for accommodating the rather bulky e-cargo bikes and for charging), supporting regulatory framework and policies for manufacturing (e.g., technical standards, licensing, etc.), and awareness raising among drivers.

MAAS IMPLEMENTATION

The implementation of the MaaS concept requires the fulfilment of a set of technology, organisation and business environment conditions. The MaaS level analysis of the project cities shows that despite the fact that some of them are still in level 0 (no integration), they are already transitioning to level 1 (integration of information). Most cities are in level 1, some transitioning to level 2 (integration of booking and payment). Thus, the cities analysed, despite their differences, reveal a slow, but steady progress towards the adoption of the features of an intelligent and integrated transport system that will enable MaaS.

There are, however, still a series of barriers that need to be overcome related to the digitalization level, as well as in the transport system and governance, before the MaaS concept implementation is feasible in developing countries.

A step-by-step approach could be desirable, starting by the gradual integration of all PTOs into the system in one digital platform and then the addition of other mobility service providers.

LESSONS LEARNED ON THE IMPACT ASSESSMENT METHODOLOGY

The assessment framework covered all relevant aspects. A gap identified by the EU

Project Officer relates to the suitability of the vehicles to serve disabled passengers. Although not formally assessed through a specific KPI, this aspect was considered in the service quality questionnaires soliciting stakeholder perceptions.

Not all the KPIs were used in assessing impacts. Even for the most detailed assessment exercise (Kathmandu demo), only 23 of the 34 KPIs were finally considered, while 7 of them were nullified due to all alternative scaled-up projects having identical scores. It can then be argued that the range of KPIs in the assessment framework is overly ambitious and could have been reduced. Although this is certainly a possibility, one needs to consider that the framework was designed to deal with a variety of interventions that might be very different in nature than those demonstrated in a specific application.

A related issue concerns the definition of KPIs and the associated data requirements. In Kathmandu, for example, this became an issue for two indicators (effect on budget, and effect on other imports), for which the city team was unable to conceive an alternative formulation, leading to the exclusion of these indicators.

Value functions is also a rather sensitive issue as they can have a significant effect on the star values. On one hand, they should be designed to differentiate sufficiently among the alternative solutions examined. On the other, a prior knowledge of the alternative solutions might permit strategic responses. A balance needs to be achieved by the moderator of the stakeholder meeting.

Another concern relates to the reliability of several of the KPI values, which depend on the skills and experiences of the individuals that provide the necessary input. This is an inherent characteristic of the MCDA techniques, which are used for assisting stakeholders reach better decisions according to their own set of values, visions, and priorities. In this respect, the suggested scaled-up project is basically the result of the collective input of all stakeholders who participate in the process of estimating the KPI weights, KPI scores and value functions.

Due to the multiplicity of its demo components, Kathmandu was the only city for which the evaluation method was implemented fully in designing the scaled-up project. Notwithstanding the limitations mentioned above, the framework as applied in this city produced the expected results. In addition to formulating the scaled-up scenario, the ex ante assessment played a critical role in the design of the demo vehicles, ensuring through several iterations that the design is compatible with financially sound operational profiles.

In terms of the tools used in the assessment, the Future Mobility Calculator (FMC) used in Kathmandu proved effective, flexible (application-specific values can be used in addition to default ones), and user-friendly as was the UNEP e-Mob calculator used in Dar es Salaam and Kigali.

Among the metaheuristics deployed in the optimisation exercise, the less popular Grey Wolf Optimiser outperformed by far the other two algorithms in terms of both effectiveness and efficiency.

CONTENTS

LIST OF ABBREVIATIONS

BAU	Business as usual
BEV	Battery electric vehicle
BRT	Bus rapid transit
CBA	Cost-benefit analysis
CBD	Central business district (Quito)
CER	Cost effectiveness ratio
CL	City Leader
CNG	Compressed natural gas
CO2	Carbon dioxide
DMQ	Metropolitan District of Quito
eMOB	e-mobility calculator (of UNEP)
e3W	Electric 3-wheeler
e4W	Electric 4-wheeler
EV	Electric vehicle
FMC	Future Mobility Calculator
GDP	Gross domestic product
GHG	Greenhouse gas
GPS	Global positioning system
GTFS	General transit feed specification
HCQ	Historic centre of Quito
IA	Impact assessment
ICE	Internal combustion engine
ICT	Information and communication technology
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal rate of return
IT	Information technology
ITS	Intelligent transport system
KPI	Key performance indicator
LCA	Life cycle analysis
LCMM	Low carbon mobility management app (Nanjing)
LEFV	Light-duty electric freight vehicle
LPG	Liquefied petroleum gas
MaaS	Mobility as a service
MCDA	Multi-criteria decision analysis
NDC	Nationally determined contribution (in the context of Paris Agreement)

NGO	Non-governmental organisation
NMS	New mobility services
NOx	Nitrogen oxides
NPV	Net present value
OEM	Original equipment manufacturer
PHEV	Plug-in hybrid electric vehicle
PKM	Passenger kilometres
PM	Particulate matter (2.5 or 10 depending on their maximum diameter)
PS	Performance standard
PT	Public transport
PTO	Public transport operator
SDG	Sustainable development goal (in the context of the UN)
SMART	Simple multi-attribute rating technique
SOx	Sulphur oxides
SUMP	Sustainable urban mobility plan
TKM	Tonne kilometres
TOE	Technology, organisation, and environment (framework for assessing MaaS)
UNDESA	United Nations Department of Economic and Social Affairs
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
VKM	Vehicle kilometres
VRU	Vulnerable road user
WP	Work package
WTW	Well-to-wheel (in relation to emissions)
3W	3-wheeler
4W	4-wheeler

1 INTRODUCTION

This report presents the work performed under Task 1.3 (Impact assessment, data collection and evaluation) of WP1 (Toolbox and evaluation) of the SOLUTIONSplus project.

Due to the long duration of the project, it was decided in May 2021 to submit an interim report (D1.6 – Part A) describing the impact assessment methodology to be followed and the early assessment activities of the project. This interim report is now obsolete as its contents have been incorporated in the present deliverable.

This introductory chapter will present the aims of Task 1.3 and its role in SOLUTIONSplus, explain the approach of impact assessment and evaluation to be followed, and define the objectives and structure of this deliverable.

1.1. TASK 1.3 AND ITS ROLE IN THE PROJECT

Task 1.3 is the last task of WP1, which in addition contains Tasks 1.1 (Toolbox for efficient e-mobility) and 1.2 (Evaluation framework, user needs and data requirements).

The general objective of Task 1.3 is to support the demonstration actions of the project by providing comprehensive impact assessments and evaluations. The following specific objectives can be extracted from the formal description of the task:

Impact assessment

- Perform comprehensive impact assessment and evaluation from economic, social, and environmental perspectives according to the assessment framework (Task 1.2), tools (Task 1.1), and data requirements (Task 1.2 and WP4)
- Perform both ex ante and ex post assessments
- Explore different perspectives such as user acceptance, environment, GHG and other emissions, air quality, traffic safety, traffic efficiency, energy efficiency, personal mobility, well-being/quality of life, sustainability, and electrical safety
- Assess the performance, feasibility and usability of the introduced services and use cases with respect to the user needs and various city circumstances, utilising and analysing the data collected

Data collection

- Ensure data collection before (baseline) and after the interventions
- Manage the collection of data on population, travel behaviour, city air quality and noise
- Coordinate, support, and assure the quality of data collected from sensors and other sources
- Prepare and define the format and scope of data collection in the demonstration projects to ensure interoperability of data
- Define technical data acquisition methods and data management systems from the vehicle fleet and infrastructure
- Draft the necessary surveys for subjective data collection during or after demonstration
- Manage and store data in a cloud-solution with special provisions for security and privacy

Evaluation

- Perform cross-cutting evaluation on selected key impact areas to gain insight on the overall potential of the e-mobility services in different urban environments around the world
- Evaluate selected demonstration project specific KPIs to address issues specific to certain types of areas or circumstances
- Document evaluations in a way that enables meaningful geographic comparisons and transferability to other settings
- Support subsequent scaling up of projects and activities in each region

By nature, Task 1.3 depends heavily on other project activities. As shown in Figure 1, the impact assessment and evaluation function of the task has been broadly defined by the evaluation framework of Task 1.2, while the assessment tools come from the toolbox of Task 1.1. The actual assessment is based on data collected by the implementation Task 4.4, although the data collection mechanism is designed and managed by Task 1.3 itself.

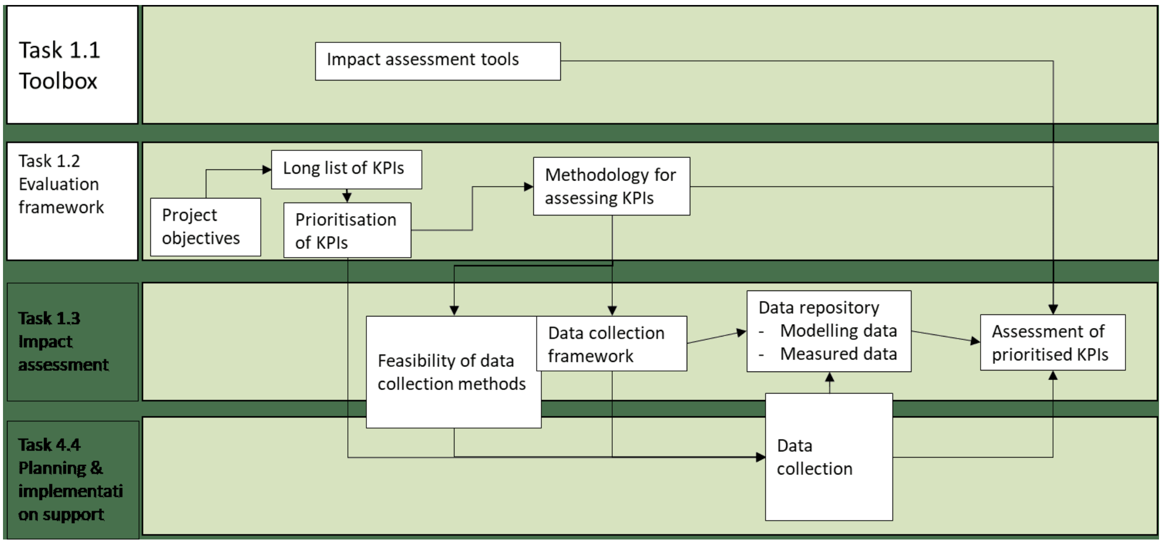


Figure 1. Required inputs from other tasks

Strong interlinkages also exist with other work packages. In addition to providing the assessment and evaluation support for the demonstration actions of WP4, which will be a critical input to the upscaling and financing plans of WP5, Task 1.3 is expected to provide inputs to the capacity building of WP2 and the business model development of WP3. Similarly, the WP3, 4 and 5 will produce data and reference models that will feed back into the toolbox and methods of WP1 and will be shared widely through capacity building (WP2) dissemination and replication (WP6), all of which are guided by the management (WP7) and ethics (WP8) work packages. Figure 2 graphically depicts these interlinkages.

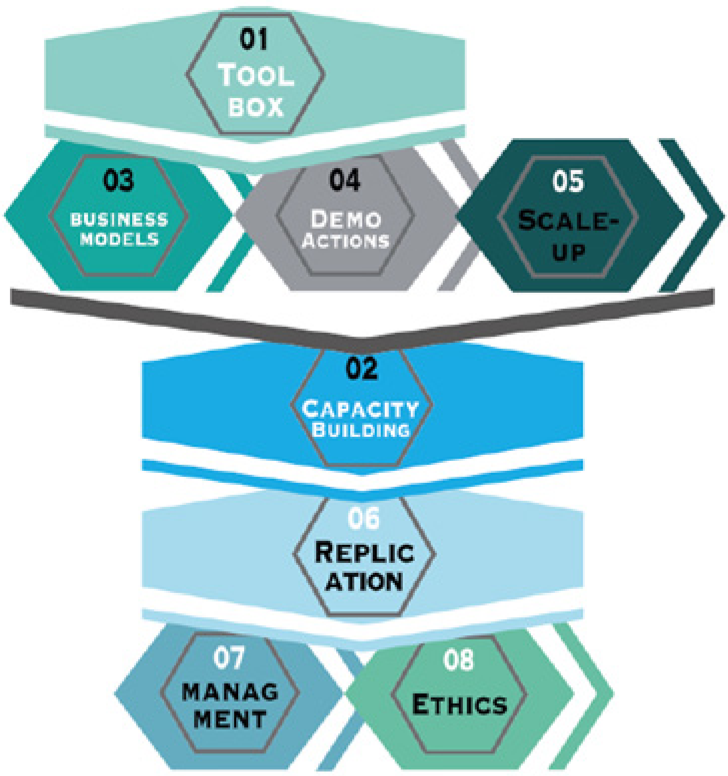


Figure 2. Interlinkages with other work packages

In addition to D1.6, Task 1.3 will produce two deliverables concerning data (D1.4 – Data collection plan; and D1.5 – Data storage repository). Therefore, data needs and possible sources are not a focal subject of the present report, which concentrates on the impact assessment and evaluation part of the task. However, reference to data needs and sources will be made whenever there is a direct connection to the assessment methods deployed.

Furthermore, the reader is warned for a certain degree of unavoidable overlapping that exists between this report and deliverables D1.2 (Evaluation framework), D1.3 (User needs assessments), D4.1 (Demonstration implementation plans), and D4.10 (Impact assessment guidance of urban e-mobility innovations) due to the interwoven nature of these documents.

1.2. OUR APPROACH TO IMPACT ASSESSMENT AND EVALUATION

A few terms need to be defined before presenting our impact assessment approach. They refer to the object of the assessment activity, which can be one of the following:

- The city-specific **up-scaled project**[1] that will be designed together with the local stakeholders based on the demonstration results. This up-scaled project constitutes the ultimate goal of each city demonstration and will be implemented after the completion of SOLUTIONSplus.
- The city-specific **demonstration project** that has already been planned together with the local stakeholders and which will be implemented by the SOLUTIONSplus consortium during the project life (2020-2024). In the

1 For enhancing reader friendliness, all terms of this report appearing **in colour** are defined in Appendix A.

occasion that the demonstration project in a city comprises of several **project components** that cannot be viewed and assessed as a single transportation system, the assessment activity will be performed for each component separately.

In terms of timing, an assessment can be:

- **Ex ante**, which takes place before the planned intervention and aims at predicting the expected impact of the activities involved.
- **On-going** (also called 'monitoring'), which takes place during the implementation phase and aims at tracking progress towards reaching the desired output and outcome.
- **Ex post**, which takes place after the completion of the planned activities and aims at examining the impacts achieved.

Due to the short duration of the SOLUTIONSplus demonstration actions, there will be no formal on-going project assessment. The monitoring requirements will be defined with the ex ante assessment and the results will be reported with the ex post one.

Impact assessment quantifies the planned and realised effects of an intervention. A major challenge in this activity is the isolation of the effects of the examined interventions from influences caused by external factors. As a matter of fact, this difficulty increases with the time elapsed since the completion of the intervention. In that sense, the assessment of **impact** is more challenging than the assessment of **outcome**, as impact denotes the longer-term effects of an activity. The usual way to address this challenge is by defining the **assessment boundaries** and the **baseline scenario**. The assessment boundaries define the scope of the impact analysis. The baseline scenario describes the situation in the project area as we would expect it to develop in the absence of the intervention under examination.

From the practical side, there are a few clarifications that need to be given here:

In relation to the ***up-scaled project,*** we need to ensure that the baseline scenario of each demonstration city includes all planned initiatives in the sector/segment of interest in the city, i.e. e-mobility in urban public/bus transport. It is only the SOLUTIONSplus activities that must be excluded.

In relation to content, the baseline description needs to be confined within the boundaries set for the assessment activity and should cover as many of the **assessment attributes** (criteria) as possible. Normally, it is the attributes related to project operations and performance that are omitted from the baseline description as the project itself is absent from this scenario.

In relation to time horizon, the baseline description should be provided for a pre-determined period. This period starts with the **base year**, which determines the status quo, and ends with the **target year**, which signifies the final year for which potential project impacts are assessed. For the needs of SOLUTIONSplus, 2020 is taken as the base year, unless more recent data become available. As for target year, we have selected focusing our analysis to 2030. This leaves sufficient time for the up-scaled project to become operational and generate the expected impacts. In addition, this year is used by the authorities in demonstration cities as milestone for target setting, while it also serves as the target year for the UN Sustainable Development Goals (SDGs).

Regarding the ***demonstration project***, the baseline scenario is identical to the so-called **do-nothing scenario**, which nullifies whatever action is foreseen by the relevant project component. For example, if the assessed component involves the electrification of a diesel bus, the do-nothing scenario examines the situation where no such electrification would take place and the diesel bus would continue operating as previously. The time horizon of the demonstration project is identical to its implementation time and its assessment will focus on **output** and outcome rather than impact.

While impact assessment is the process of collecting and analysing quantitative and qualitative data for the purpose of improving current performance, evaluation is described as an act of benchmarking based on a set of standards. As such, it follows the assessment activity and aims at horizontal comparisons and the investigation of the projects' scalability and transferability.

The impact assessment and evaluation activities of Section 1.1, can then be performed through:

- The definition of the attributes that will delineate the assessment of both the demonstration and up-scaled projects taking into consideration all economic, social, and environmental perspectives mentioned in the Task 1.3 description
- The ex ante assessment of the demonstration/component projects that provides estimates of the expected outcome of the planned SOLUTIONSplus demonstration activities in comparison to the do-nothing scenario
- The ex post assessment of the demonstration/component projects that estimates the observed outcome of the planned SOLUTIONSplus demonstration activities in comparison to the do-nothing scenario and the relevant ex ante assessment
- The description of a baseline scenario for each demonstration city that identifies existing urban transport trends and projects the relevant attribute values for the target year 2030 in a scenario where there are no SOLUTIONSplus interventions
- The (ex ante) assessment of the up-scaled project that quantifies the expected impact of this project for the target year 2030 in comparison to the baseline scenario
- The evaluation of selected attributes in each demonstration city to address specific interests and sensitivities
- The cross-cutting evaluation of selected impact areas to examine the scalability and transferability of the demonstrated technologies, as well as the corresponding preconditions.

1.3. STRUCTURE OF THE REPORT

Due to the amount of information reported, deliverable D1.6 consists of 11 volumes. The one at hand is the first one providing an overall overview of the activities and results achieved. In addition to the present introduction, this volume contains three more sections. Section 2 outlines the assessment methodology, presents the KPIs and tools to be used for their estimation, and suggests some initial sources for collecting the necessary data. Section 3 summarises the activities performed, and results achieved in the ten demo cities of the project. The last section of this volume is devoted to horizontal comparisons across geographical areas and the identification of lessons learned in terms of user needs, the passenger and freight vehicles assessed and the potential implementation of MaaS applications.

The impact assessment of the demonstration and up-scaled projects in the 10 SOLUTIONSplus living labs is presented in a separate volume of D1.6 for each demo city. Although there might be differences in the structure of each city volume reflecting the specific composition of the demo activities, they generally consist of five thematic areas. The first one presents the general urban transport setting, the main challenges faced, a brief description of the demonstration project and its components, and the user needs as they have been reported by the city stakeholders. The second one is devoted to the prioritization of the KPIs to reflect the specific city needs and KPI estimation methods if needed due to the format of the available data. The third theme presents the assessment of the demonstration project (both ex ante and ex post). It is worth mentioning that the demonstrative nature of the planned activities and the small scale of the interventions might render some aspects of this assessment either trivial or completely impossible. In such cases, the report will only present rough estimates if any. The assessment of the up-scaled project including the baseline scenario is dealt with in the fourth theme. Each city volume is completed with a discussion on topics of special interest to the respective area.

2 METHODOLOGY

The substantial differences in objectives, scale, and scope between the up-scaled and demonstration projects in the project cities call for different methodologies in assessing their impact and outcome respectively. The corresponding methodologies are presented in the two main headings of this section.

2.1. ASSESSING THE IMPACT OF THE UP-SCALED PROJECT

Ideally, a bankable up-scaled project promoting innovative and integrated e-mobility solutions in the urban transport of each demonstration city should result from the SOLUTIONSplus. The fact that, particularly in the developing world, e-mobility is still in its infancy adds to the complexity of promoting sustainable urban transport mainly due to the need to address the relevant knowledge gap. The requirement to account for existing perceptions of e-mobility which, in fact, can differ across stakeholder groups, render the usual socio-economic cost-benefit analysis insufficient for this application. A multi-criteria decision analysis (MCDA) method was preferred due to its ability to consider aspects not easily monetised.

As explained in D1.2, the method described here will be used to compare alternative up-scaled project designs and select the one that meets user needs in a way that maximises value to the local stakeholders given their set of preferences and priorities. After briefly presenting the principles of the method deployed, the following sub-headings describe the attributes (KPIs) that enter the assessment and the practical steps required for its proper implementation.

2.1.1. The MCDA method deployed

MCDA consists of several different techniques that assist decision-makers to approach often complex problems and reach decisions consistent with their own value judgments. This is done by breaking down complicated decisions into smaller ones that are easier to handle and by aggregating them back through a logical process (Barfod, 2020).

The MCDA technique selected for the SOLUTIONSplus application is called Simple Multi-Attribute Rating Technique (SMART). It was selected because:

- The logic of the method is easily comprehensible even by stakeholders with limited exposure to project assessment methods
- Its structure is similar to that of cost-benefit analysis (CBA) often leading to a combination of these two methods (Barfod et al., 2011)
- It is suitable for analysing problems with a large number of criteria
- It enables the introduction of additional alternatives following completion of the first round of assessments

In addition to the set of possible alternatives to be assessed, which in our case will be the alternative up-scaled project designs examined, SMART involves three basic blocks: the set of attributes (criteria) to be used for the assessment, the performance of each alternative against these attributes (**attribute scoring**), and the preference structure of the decision makers (**attribute weighting**). SMART uses an additive model to connect these blocks:

$$V(a) = \sum_{i=1}^{m} w_i \, v_i(a)$$

where:

$V(a)$ = the overall rating of alternative a

$v_i(a)$ = the score (performance) of alternative a against attribute i ($i=1,\dots,m$)

w_i = the weight (relative importance) that the decision makers assign to attribute i

$$[0 \le w_i \le 1] \text{ and } \sum_{i=1}^{m} w_i = 1$$

The method selects the alternative with the highest overall rating $[V(a)]$ and requires a **sensitivity analysis** to examine how robust the selection is to changes in the scores and weights used in the analysis. The abovementioned blocks are presented below.

2.1.2. The SOLUTIONSplus attributes

The cumbersome process for selecting Key Performance Indicators (KPIs) is described in D1.2. The selection was based on the following criteria:

- The selected KPIs should be practical, in the sense that they can cover all perspectives mentioned in the Task 1.3 description, while accommodating all planned demonstration/component interventions and their differences in scope/ambitions
- The selected KPIs should facilitate a common impact assessment approach enabling cross-cutting evaluations
- The selection should be built on solid theoretical foundations, in the sense that

the KPIs need to be mutually exclusive to avoid potential double counting
- The selected KPIs should be able to lead to bankable projects at the end of SOLUTIONSplus

To cope with the conflicting nature of the first two criteria listed above (detailed enough to express component-specific impacts but broad enough to enable horizontal evaluations across project cities), the KPIs were organised in four different levels. The indicators of the first three levels (hereby denoted as L1, L2 and L3) are of the broad nature required to express impacts at a higher (city) context and enter the cross-cutting evaluations. Their estimation is, therefore, mandatory. The hierarchical structure of these attributes is presented in the tree of Figure 3.

Note the use of two different terms: attributes and KPIs. Although in MCDA the term 'attribute' denotes an assessment criterion, while the term 'indicator' (KPI) signifies the metric used for estimating a specific attribute, in the general context of this report these terms are used interchangeably to refer to impact assessment criteria. As will be explained in Section 2.1.3 below, the introduction of two rather than one term serving this purpose enables expressing subtle differences in the specific context of attribute scoring. The definition of the indicators corresponding to the attributes of Figure 3 is provided in Appendix B and summarised in Table 1.

As shown in Figure 3, the impact of the up-scaled projects will be assessed through 34 L3 KPIs organised in six L1 groups. The first one among these groups, named 'effect on project finances,' is the only one referring to the strict boundaries of the project implementing agency. More specifically, the L2 group named 'financial viability' is identical to the usual financial CBA and, as such, is of value to WP3 (Business models). It is worth mentioning that this L2 indicator is accompanied by the 'availability of financial resources' one to address possibilities of raising external funding in case of a financially unsustainable project which, however, generates social benefits sufficient to cover the corresponding financial losses. The connection to the financing/bankability content of WP5 is thus facilitated.

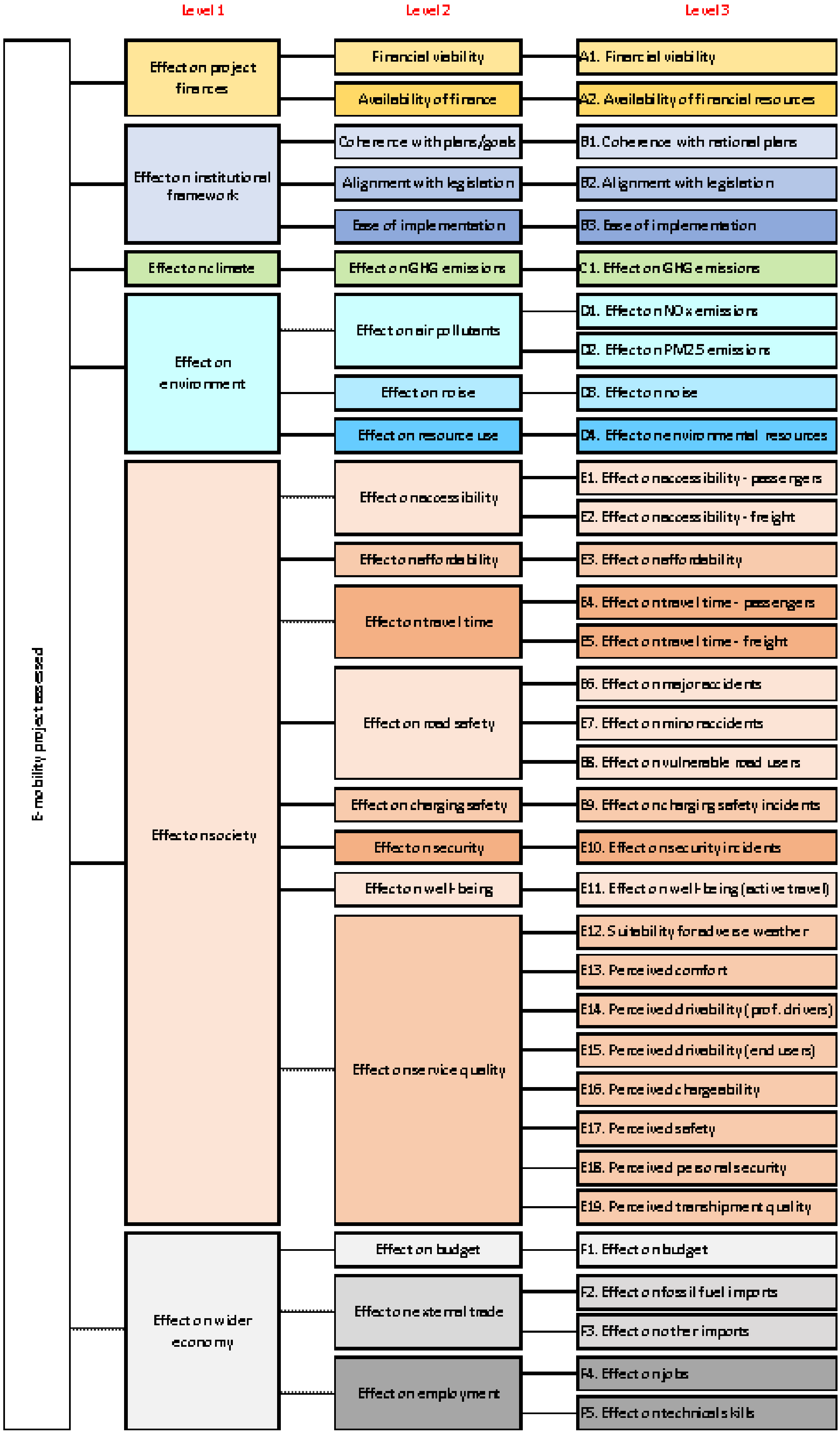


Figure 3. The SOLUTIONSplus attribute tree

Table 1. Definition of the indicators to be scored

KPI - Level 1	KPI - Level 2	KPI - Level 3	Unit of KPI level 3V
Effect on project finances	Financial viability	NPV (Net present value)	Euro
		IRR (Internal Rate of Return)	%
		Payback period	Years
		CER (Cost effectiveness ratio)	Euro/unit of effectiveness
	Availability of finance	Availability of financial resources	Likert scale
Effect on institutional framework	Coherence with national plans and development goals	Coherence with national plans and development goals	Likert scale
	Alignment with supra-national/national/city legislation & regulations	Alignment with supra-national/national/city legislation & regulations	Likert scale
	Ease of implementation (in terms of administrative barriers)	Ease of implementation (in terms of administrative barriers)	Likert scale
Effect on climate change	Effect on GHG emissions	Amount of carbon avoided (% change compared to baseline)	%
Effect on environment	Effect on air pollutants	NOx emissions avoided	%
		PM2.5 emissions avoided	%
	Effect on noise	Perception of the impact on noise & measurements	Likert scale & dB(A)v
	Effect on environmental resources	Relation to circular economy	Likert scale
Effect on society	Effect on accessibility	Population proportion with convenient access to public transport	%
		Access to pickup/delivery locations (freight)	Likert scale
	Affordability of e-vehicle services	Percentage change in price per kilometre	%
	Effect on travel time	Change in travel times due to e-mobility services (personal travel)	%
		Change in travel times due to e-mobility services (freight)	%
	Effect on road safety	Perceived change in road accidents with fatalities/ serious injuries	Likert scale
		Perceived change in road accidents with minor injuries/material damage	Likert scale
		Perceived change in road accidents involving VRUs	Likert scale

Effect on society	Effect on charging safety	Likelihood of occurrence and potential severity of associated risks	Likert scale
	Effect on security	Likelihood of occurrence and potential severity of associated risks	Likert scale
	Effect on well-being due to active traveling	Change in active kilometres	Walking-eq. kilometres
	Quality of e-mobility services	Suitability for adverse weather conditions	Likert scale
		User perception of comfort	Likert scale
		Ease of driving - professional drivers	Likert scale
		Ease of driving - other users	Likert scale
		Ease of charging/refuelling	Likert scale
		Perception of safety	Likert scale
		Perception of personal security	Likert scale
		User perception of continuity of journey chains, incl. transhipment to other modes	Likert scale
Effect on wider economy	Effect on national/local budget	Percentage change in relevant national/local budget	%
	Effect on external trade	Percentage change in fossil fuel imports	%
		Change in imports of vehicles/parts	Euro
	Effect on employment	Number of additional jobs	No unit
		Number of skilled positions required	No unit

Among the other L1 KPI groups, the climate related, environmental, social, and economic ones refer to the boundaries of the city society and include the impacts examined in a usual socio-economic CBA. In this way, the SOLUTIONSplus attributes build on both financial and socio-economic CBA. Moreover, an 'institutional/political' group has been added to the analysis to investigate the position of the proposed up-scaled project within the prevailing political and institutional framework of the corresponding demonstration city, further strengthening the ties to WP5. Although this group of KPIs can be seen as pre-conditions for e-mobility rather than impacts of its promotion, it was decided to include them in the attribute list because in some cases the planned demonstration projects aim at increasing the e-mobility friendliness of the institutional status quo.

Unlike the attributes of Figure 3, the Level 4 (L4) KPIs are needed to capture mostly technical and operational aspects of the up-scaled projects that are specific to the particular solutions involved. In this sense, they are considered as providing input to the L2/L3 indicators and are excluded from direct impact assessment to avoid double counting. An indicative list of L4 KPIs is provided with D1.2. Nevertheless, many of these indicators will have to be considered in estimating the corresponding L2/L3 KPIs and, as such, will have to be presented in the descriptive assessment part of the scoring procedure (refer to Section 2.1.3). The common ones among them are presented in Table 2.

Table 2. Common Level 4 indicators

KPI - Level 1	KPI - Level 2	KPI - Level 4
Demand	Population	Number
	GDP growth rate	%
	Total travel time	Total time spent travelling per day per person [min per day]
	Average distance travelled	Average distance travelled by type of vehicle
	Awareness of e-mobility services	Awareness of e-vehicles as an option to make the journey [Likert scale]
Supply	E-vehicles - fleet	Percentage of EVs of various types (BEV, PHEV, etc.) in the city fleet by category (bus, mini-bus, 3-wheelers, etc.)
	E-vehicles - emissions	Emission standards (EURO 0, EURO I, etc.) of the fleet
	E-vehicles - sales	Number of EVs entering the fleet each year
	E-vehicles - operational	Average driving speed
Use	Modal split and multimodality	Share of travel modes (modal split)
		Number of multimodal trips including use of e-vehicles [% of all trips]
		Number of first/last mile trips with e-vehicles (personal transport)
		Number of first/last mile trips with e-vehicles (freight)
	Average distance travelled in EV	Average distance travelled with e-vehicles per day [km]
	Market share of e-mobility	Number and type of trips made with an e-vehicle [% of all trips]
	Interaction	Interaction with other road users [Likert scale]
Climate related	Impact on GHG emissions	Carbon footprint (gCO2/p-km)
Social	Affordability of e-vehicle services	Ticket price (freight: Cost of transport)
	Impact on road safety	Number of road accidents involving vulnerable road users
		Number of traffic related near accidents/ dangerous situations involving VRUs
	Impact on traffic network efficiency	Impact on congestion
	Quality of e-mobility services	Perception of traffic efficiency (congestion)
	Impact on well-being (physical)	Change in exposure to emissions
Economic	Impact on employment	Change in the required person work-years
		Number of new businesses

2.1.3. Attribute scoring

Scoring is the process of assigning a value to the performance of an alternative against a specific attribute (criterion). In the terminology of the SMART model of Section 2.1.1, the scoring of alternative a against attribute i is the process of estimating the partial value $v_i(a)$. This process needs to be repeated for all alternatives and all attributes. According to D1.2, for the SOLUTIONSplus application, the partial values $v_i(a)$ are expressed in stars in a 5-star scale.

Since the impact of a project against a certain criterion is always assessed in comparison to the baseline scenario, the scoring process of an alternative up-scaled project design against a specific attribute involves the following steps:

Step 1:

Estimation of the **attribute value** for the target year under the up-scaled project alternative examined. The attribute value is defined as the numerical value of the indicator of Table 1 that corresponds to the attribute being scored. The values of quantitative attributes are calculated through specialized tools or measured by special sensors as described in the relevant sub-heading below. For qualitative attributes, the attribute values can be a number on a qualitative scale or direct ratings (refer to the sub-heading on value functions below).

Step 2:

Estimation of the attribute value for the target year under the baseline scenario.

Step 3:

Estimation of the **KPI value** for the target year. This is defined as:

KPI value = Attribute value(up-scaled project) – Attribute value(baseline)

In cases of attributes involving indicators (refer to Table 1) that are defined as a differential to the baseline scenario (e.g. emissions avoided, number of additional jobs, etc.) or such a differential is embedded in their definition (e.g. **NPV, IRR, payback period**), Steps 2 and 3 are omitted and the KPI value is identical to the attribute value of Step 1. The term **descriptive assessment** is used in D1.2 to denote the work performed under Steps 1 to 3.

Step 4:

Transform the KPI value of Step 3 (or Step 1 under certain conditions) to a **KPI star value** through one of the methods described in the sub-heading on value functions below.

ESTIMATION OF ATTRIBUTE VALUES

The measurable indicators among the L3 KPIs of Table 1 are listed in Table 3. Those falling in the social and economic fields (appearing in black) are calculated based on the national/city statistics, other specialised publications or direct measurements. The remaining (appearing in red) can generally be calculated through available methods and tools. This section aims at briefly presenting these methods and tools together with the corresponding data requirements.

Financial costs/revenues

NPV, IRR, payback period, and CER (cost effectiveness ratio) are four well-defined terms used in the financial appraisal of projects. NPV measures the value of a project and its costs, and since current cash flows have more value than future ones, future cash flows are discounted using a chosen discount rate. NPV calculation requires information on the annual costs and revenues of the project during the impact assessment period.

Table 3. Measurable Level 3 indicators

Level 1	Level 3 KPIs
Financial costs /revenues	NPV (Net present value)
	IRR (Internal Rate of Return)
	Payback period
	CER (Cost effectiveness ratio)
Climate change	Amount of carbon avoided (% change compared to baseline)
Environment	NOx emissions avoided
	PM2.5 emissions avoided
	Noise measurements – difference in dB(A)
Society	Population proportion with convenient access to public transport
	Percentage change in price per kilometre
	Change in travel times due to e-mobility services (personal travel)
	Change in travel times due to e-mobility services (freight)
	Change in active kilometres
Wider economy	Percentage change in relevant national/local budget
	Percentage change in fossil fuel imports
	Change in imports of vehicles/parts
	Number of additional jobs
	Number of skilled positions required

Project cost estimation requires detailing all the activities for the up-scaled project, and once this has been done, the costs must be distributed over time. The costs can be broadly categorised under proposal preparation, construction, and operation/maintenance. Similarly, all revenue generating activities will need to be identified, and revenues divided over time. Note that in the case of transportation projects, the revenues would very much depend on the demand for the services provided by the up-scaled project.

Once costs, revenues and discount rates are defined, NPV can be easily calculated using the Excel function NPV. Several financial models include this function, and more detailed guidance is available in TNA Financing Guidebook (Canu et al., 2020)[2]. A positive NPV indicates that the project is financially viable, and a negative NPV means the project is not financially sustainable. A higher NPV is more attractive than a lower one.

IRR is the discount rate at which the NPV of all cash flows from a particular project is zero and again can be calculated easily in Excel. The data required for calculating IRR are identical to those of NPV. If the IRR is negative, without additional revenues, grants or subsidies, the project is probably not financially viable. If the IRR is positive but below the discount rate, the project is financially self-sustainable but may be of limited interest to the private sector, as it does not generate a profit. If the IRR is positive and above the discount rate, the project is financially viable. A higher IRR is more attractive than a lower one.

The payback period is the time required to recover the cost of an investment. Although it uses the same cost and revenue flows of NPV and IRR, it does not consider the time value of money and, therefore, can be calculated much easier than the other indicators. A shorter payback period is more desirable than a longer one.

CER is used for assessing projects/components, mainly in the public sector, where revenues either do not exist or are very difficult to monetise. It relates the costs of a project to its key outcomes. The method identifies the costs of the project and ascribes monetary values to them. It then identifies the primary outcome of the project and quantifies it in terms of 'units of effectiveness' (e.g., number of lives saved, volume of waste collected, etc.). CER is obtained by dividing total costs by the units of effectiveness. The lower a project's CER is, the more desirable its undertaking becomes.

Climate related and environmental indicators

CO2 is the most abundant greenhouse gas found in the atmosphere and is associated with the combustion of fossil fuels. The internal combustion engines (ICE) of vehicles are responsible for about 24% of global CO2 emissions from energy (IEA, 2020). The transport related CO2 mainly comes from the combustion of diesel, petrol, compressed natural gas (CNG) and liquefied petroleum gas (LPG). The combustion of fossil fuels in engines is also associated with many other pollutants (SOx, NOx, PM2.5, PM10, volatile organic compounds, etc.) which affect the local air quality and, therefore, are examined here together with CO2. There are two approaches for calculating energy demand and CO2 emissions: (a) top-down, and (b) bottom-up. The selection among them depends on the availability of data.

(a) Top-down approach

The top-down approach involves the preparation of energy balances. It relies on information available from energy suppliers, such as oil companies, electricity utilities, etc., and large consumers -- e.g. railways, transport utilities, etc. Energy balances are a way of representing aggregate energy flows from energy suppliers to consumers and are used as an accounting tool for estimating energy-related emissions. Table 4 lists the data required for compiling the energy balances covering transport sector.

2 A detailed description along with a solved example is available in the TNA Financing Guidebook of how to calculate NPV, IRR and payback period https://tech-action.unepdtu.org/wp-content/uploads/sites/2/2020/09/finance-guide-for-implementation-of-technology-action-plans.pdf

Table 4: Energy balance

DATA REQUIRED	DESCRIPTION	DATA SOURCES
Consumption of fossil fuels from transport	Diesel, petrol, CNG, LPG consumption in the city for transport	Retail outlets or fuel company supply/storage depots
Consumption of electricity for transport	Electricity consumed for metro/ trams/suburban trains/other rail/electric vehicles	Railways and mass transit operators or electricity suppliers

CO2 emissions are calculated from the total fuel consumption based on the CO2 content of fuels. National emission factors are published in National Communications, and Biennial Update Reports submitted to the UNFCCC. If these are not available, default factors available from IPCC or other global databases should be used (refer to Table 5). The top-down approach cannot however be used for estimating local pollutants.

Table 4: Energy balance

FUEL	GIGA GRAM CO2/PETA-JOULE	KG CO2/TONNE OF FUEL	KG CO2/LITRE OF FUEL
Petrol	69.30	3101	2.30
High speed diesel (diesel)	74.10	3214	2.71
Compressed Natural Gas (CNG)	56.10	1691	1.69*
Liquefied Petroleum Gas (LPG)	63.10	2912	2.91*

(*) Kg CO2/ kg of fuel, Source: IPCC (2006)

(b) Bottom-up approach

In the bottom up approach, person trips (or freight trips per unit weight) using motor vehicles are the basic unit of travel that ultimately leads to fuel demand and GHGs. GHG emissions are often calculated using the following identity

$$Total\ GHG = \sum_i \sum_j A * S_i * I_i * F_{i,j}$$

where:

A = the total transport activity (in PKM)

S_i = the share of PKM by mode i

I_i = the fuel efficiency of mode i

$F_{(i,j)}$ = emissions per unit of fuel by mode i and type of fuel j

3 http://unfccc.int/national_reports/non-annex_i_natcom/reporting_on_climate_change/items/8722.php (Accessed: 30/11/2020)

4 http://www.ipcc-nggip.iges.or.jp/EFDB/main.php (Accessed: 30/11/2020)

There are different tools and methodologies available for analysing the impacts of various mitigation actions on CO2 emissions. We propose using the e-Mobility calculator of UNEP for making the calculations in conjunction with the UNFCCC Compendium on Greenhouse Gas Baselines and Monitoring[5] for understanding the methodology. The e-Mobility calculator is an open-source Excel-based tool. It requires the following input data: Socio-economic data (GDP and population), vehicle stock and sales, vehicle technology shares and techno-economic vehicle parameters. In addition to CO2 emissions, the tool is also able to calculate the air pollutants PM and NOx.

GDP data at national level are available from World Economic Outlook (World Bank), and similarly, population data at national level are available from World Urbanization Prospects (UNDESA). In the absence of city-level data and future projections, these can be taken as a percentage of national data. Information on vehicle stock, their mix by type, etc. can be obtained from vehicle registration records that are generally available from local/regional transport authorities. The techno-economic vehicle parameters should be collected during the demonstration implementation phase.

Noise measurements

In-vehicle noise measurements are required in conjunction with the perceptions of the EV drivers/users for assessing the effect on noise. The freely available NoiseCapture app (only available for Android) needs to be downloaded and installed on the devices that will be used for the noise measurements. In case of using multiple devices, they must be properly calibrated (this requires a reference device: an acoustic calibrator, a calibrated smartphone, a sound level meter, etc.). Ideally, the device(s) should also be able to track information on geographic positioning.

Accessibility to public transport services

The SDG 11.2 indicator, defined as the proportion of the population that has convenient access to public transport will be used for this purpose. The SDG 11.2 indicator values will be calculated with support from DLR, using openly available data on population and street network. The DLR open-source tool UrMoAc will be used for calculating the accessibility values[6]. The required data inputs include:

- Population distribution in the city (Source: DLR World Settlement Footprint)
- Street network for walking (OSM-OpenStreetMap)
- Public transit stops (locations, ideally including different entrances)

Every city has one percentage value describing the current state of accessibility. The difference in the indicator value caused by the up-scaled project is the corresponding KPI value.

Value functions

The transformation of a KPI value to its star equivalent is achieved through the so-called value functions. Before presenting the various types of value functions, it is necessary to define the scale used. This is done through assigning numerical values to two reference points, the minimum point (1 star) and the maximum point (5 stars). When,

5 https://unfccc.int/sites/default/files/resource/Transport_0.pdf
6 GitHub - DLR-VF/UrMoAC: A tool for computing accessibility measures, supporting aggregation, variable limits, and intermodality.

in developing the scale for a particular KPI, the minimum point (1 star) is given the KPI value of the least performing alternative under examination, and the maximum point (5 stars) takes the KPI value of the best performing alternative, the resulting scale is a local scale, defined only by the set of alternatives under examination. However, when the end points are defined by the best and the worst conceivable performance on a particular KPI, the resulting scale is a global scale, defined by reference to a wider set of possibilities (Barfod, 2020). Although the definition of a global scale requires more effort than that of a local scale, this approach was selected for the SOLUTIONSplus project because: (i) it can be used for scoring alternatives added after the definition of the scale, and (ii) it enables the definition of weights (refer to Section 2.1.4) before forming the set of alternatives to be examined.

Once the end points are determined (in our case, by the minimum and maximum conceivable KPI values respectively), the intermediate scores are determined through one of the following three ways:

1. Definition of a quantitative value function. This method is applied when the performance against the attribute of interest is expressed through a measurable KPI value. In the example of Figure 4, the X-axis depicts the measurable KPI values, while the corresponding KPI star values are shown in the Y-axis. After determining the end points (2 for 1-star and 40 for 5-stars), the decision-maker is asked to identify the point on the X-axis which corresponds to the 3-star value. To help the decision-maker identify this midpoint value, it may be helpful to begin by considering the midpoint on the KPI value (X-axis) and then pose a question regarding which of the two halves is the most valuable. The considered point can then be moved towards the most preferred half and the question repeated until the midpoint is identified. The next step would then be to find the midpoints between the two endpoints and the previously found midpoint. It is generally accepted that 5 points (2 endpoints and 3 midpoints) give sufficient information to enable drawing the value function.

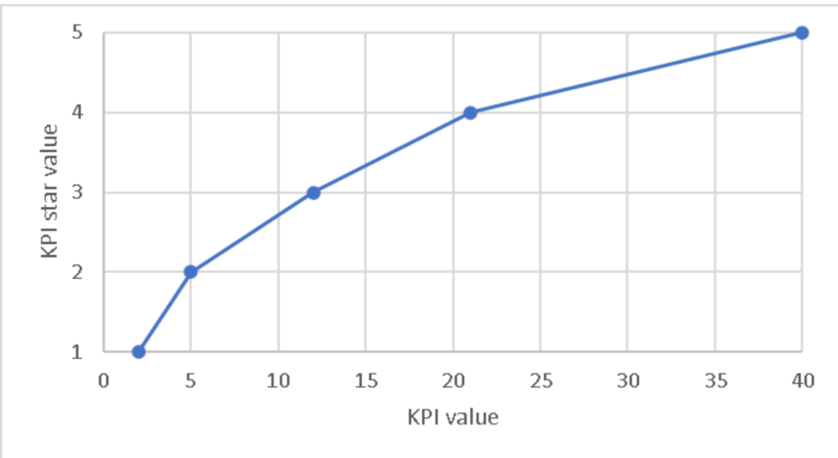


Figure 4. Example of a quantitative value function

2. Construction of a qualitative value scale. In the absence of a measurable KPI value, it is necessary to construct an appropriate qualitative scale. Both the end and intermediate points of such a scale are defined descriptively through concepts familiar to the decision maker. The Beaufort scale for measuring the force of the wind based on its effects on land and the sea surface is an example of such a scale in regular use.

3. Direct rating of the alternatives. This is the simplest method followed when none

of the other two is feasible. For the global scale approach considered here, the decision maker is asked to define the two alternatives (not necessarily among those examined) that perform in the best and worst manner to take the 5-star and 1-star values respectively (Belton and Stewart, 2002). Following the definition of the end points, all alternatives under consideration are then positioned directly on the scale to reflect their performance relative to the two end points.

2.1.4 Attribute weighting

Given that not all attributes (criteria) of an assessment carry the same weight, it is desirable to define their relative importance. Using the terms of the SMART model of Section 2.1.1, the weighting of attribute i is the process of estimating the weight w_i. The weighting technique that will be used in SOLUTIONSplus is called swing weighting and is considered as the most solid theoretically since it considers the scaling effects of the alternatives in addition to their relative importance.

Swing weights are derived by asking the decision maker to compare a change (or swing) from the least-preferred (1-star) to the most-preferred (5-star) value on one attribute to a similar change in another attribute (Goodwin and Wright, 2014). The weighting process involves three steps:

Step 1:
: Ask the decision maker to imagine that all attributes considered (members of the same family) swing from minimum to maximum value (1-star to 5-star) and select the most important among these swings.

Step 2:
: Assign a weight of 100 to the attribute selected in Step 1. Then assign a weight between 0 and 100 to all other attributes of the same family by answering the question: If in the scale of importance, the swing from 1 to 5 stars of the attribute selected in Step 1 is valued 100, what would be the value of swinging each one of the other attributes from 1 to 5 stars?

Step 3:
: Normalise swing weights to have a sum of 100. Actually, this function is performed automatically by the evaluation tool developed under Task 1.2 and described in D1.2.

In multi-level attribute trees, as is our case, the procedure described above should be repeated for defining relative weights within all attribute families, i.e. groups of same-level attributes sharing the same parent.

2.1.5 Handling multiple stakeholders

The scoring and weighting procedures described above concern a single decision maker. In our case of multiple stakeholders, an aggregation process should be applied for every score or weight they provide. This is achieved through the so-called Delphi method as follows (Goodwin and Wright, 2014):

Step 1:
: All relevant stakeholders in a city receive from the City Leader (CL) a file soliciting stakeholder input (scores or weights) and providing instructions. Alternatively, the CL can obtain this input directly while interviewing the stakeholders.

Step 2:

Once this input is provided, the CL calculates the mean values of all relevant variables (scores or weights) and contacts the stakeholders once again asking them whether they want to reconsider their original figures in view of the mean values of the group that are shown to them.

Step 3:

The process is repeated until either a consensus is achieved or none of the stakeholders is willing to modify their views anymore. Usually, 2 or 3 rounds are sufficient to reach this point.

Step 4:

The aggregate group variables (scores or weights) are the mean values calculated on the latest stakeholder inputs.

2.2 ASSESSING THE OUTPUT/OUTCOME OF THE DEMONSTRATION PROJECT

The scope of a demonstration project is much more limited in comparison to its up-scaled counterpart due to different functionalities. In contrast to an up-scaled project that aims at generating impact, the objective of a demonstration project is to generate the knowledge/information required to design a proper up-scaled project. As such, its assessment is confined to the project output and outcome.

The output of a project describes the quality, quantity, and timeliness of the deliverables of the project at the time of conclusion. Thus, it includes all products, services, or other results (e.g. reports, papers, etc.) that a project generates. In our bus electrification example of Section 1.2, the output would be the electrified bus itself together with all relevant documentation. Outcome describes the immediate benefits that a project is designed to deliver. The reduced fossil fuel consumption, emissions and noise are, thus, included in the outcomes of our bus electrification example.

To be able to assess the output and outcome of a project, then, it is necessary to look at all its constituent components, unless these form a coherent system that can be assessed as a whole. It is also worth noting that output and outcome are assessed against a scenario of no intervention (do-nothing scenario).

According to these definitions, the assessment of each city demonstration project should provide the following information for each of the constituent components:

Ex ante assessment

Output:

- A detailed description of all expected tangible and intangible deliverables of the component
- Technical specification of hardware and software to be delivered

Outcome (in comparison to the do-nothing scenario):

- Expected input in terms of needed resources (labour, facilities, knowhow, financial resources, etc.)
- Expected effects on the weighted KPIs of Table 1 and the common KPIs of Table 2. The selection of KPIs to be assessed depends on the nature of the component under examination and will be decided by the city teams

Other:
- Identification of relevant literature and data sources
- Identification of data gaps that need to be filled during the implementation of the component under examination

It is worth noting that the abovementioned expected inputs and effects will be based on the views of the relevant stakeholders and published literature preferably specialising on the demonstration city examined. Furthermore, any pre-conditions or other assumptions used in the assessment should be clearly stated in the accompanying text.

Ex post assessment

Output:
- A detailed description of all realised tangible and intangible deliverables of the component
- Technical characteristics of delivered hardware and software
- Accompanying documentation

Outcome (in comparison to the do-nothing scenario):
- Resources used (labour, facilities, knowhow, financial resources, etc.)
- Realised effects on all weighted KPIs of Table 1 and common KPIs of Table 2.

The abovementioned inputs and effects will be based on information collected during the implementation of the corresponding component. This information will be generated by direct measurements, model results or purposely built surveys. Any pre-conditions or other assumptions used in the assessment should be clearly stated in the accompanying text. To the extent possible, the output/outcome of the ex post assessment will be further compared to the expectations of the ex ante analysis to identify potential failures and investigate the causes.

3 DEMONSTRATION ACTIVITIES AND RESULTS

3.1. THE HANOI DEMONSTRATION

Vietnam is experiencing rapid economic growth and combined with an increase in urban population growth this results in a rapid increase in transport demand. Both the number of vehicles has sharply increased, as are consequences of this increase in vehicle kms. Keeping up with the challenges brought about by further urbanization, particularly in terms of providing proper transport infrastructure and support services, is becoming a key issue for the country.

Hanoi e-mobility for last-mile connectivity

The demonstration project focusses on boosting the ridership and effectiveness of the currently running BRT and the forthcoming metro rail. The demonstration consisted of a trial with 50 shared e-mopeds to test the sharing system to facilitate the traveling from BRT stop to a shopping mall and vice versa. Plans are that the sharing system will be replicated to other locations in the city, probably connecting the Metro terminal with residential areas. The project's objective was to form the habit of using green traffic modes and raising awareness of environmental protection for people of Hanoi city, application of science and technology in the management and operation of public transport and connection of public transport in the city.

Relevant KPIs

The priorities given to each attribute (KPI) are derived from interactions with the relevant stakeholders, the weighting of the attributes for the Hanoi demonstration occurred in combination with interviews held with stakeholders. By analysing the cumulative weights of indicators, one can observe that effect of society emerged as the main priority of the stakeholders, followed by effect on the environment (2nd), effect on institutional framework (3rd), effect on project finances (4th), effect on wide economy (5th), and effect on climate (6th). It is interesting to notice that the society indicator group had almost twice the weight of the group with the second highest priority (effect on the environment). Another interesting aspect of the results refer to the fact that effect on the environment, such as effect on air pollutants, noise and resource use emerged as the second highest priority group, whereas the effect on climate (GHG emissions) emerged as the last priority group.

Scale up

Given the plans to potentially expand the pilot to other locations in Hanoi, we have used a scale up scenario given 50 identical routes to the pilot. In this pilot we have assumed that all routes use the same amount of 50 shared e-mopeds as in the pilot. We have used 275 trips in total (5.5 per moped), which is the break-even point for financial viability. These e-moped trips will replace the shuttle trips, on the basis of passenger kms (pkm). The results of the pilot and the results from the scale up can be found below.

Figure 4. Example of a quantitative value function

HIGH LEVEL KPI	LOWER LEVEL PI	FINDINGS
Project finances	Financial viability	The explorative analysis in the ex-ante assessment focussed on the break-even point as an indicator for financial viability. It showed that to break even at the end of the e-moped lifetime 275 daily trips are required per fleet of 50 vehicles. Given the popularity of the route and the large operational time window this should be achievable, given that there is not a more favourable transport option available to travellers.
	Availability of financial resources	Regarding the availability of financial resources, it appears that funding can be available for scaled-up e-mopeds project. This conclusion is supported by both public authorities and private sources. The net present value of the scaled-up project is negative. This implies that, purely from a financial perspective, the project isn't self-sustaining and would require external funding. However, given the financial interest coming from public authorities and private parties, as well as the market share that motorcycles have in the transport modes in Vietnam, it is reasonable to expect that there would be financial resources available to make such a scaled-up version of the project possible.

HIGH LEVEL KPI	LOWER LEVEL PI	FINDINGS
Institutional framework	Coherence with national plans and development goals Alignment with supra-national, national, city legislation & regulations Ease of implementation (considering Administrative barriers)	For all of these components, the only one in which some uncertainty was experienced was the alignment with policies and regulations. The reason for it is that, although multiple examples of policies and legislations related to the e-mopeds project were identified, the available information is not sufficient to fully ascertain whether the proposed project is fully compliant with all relevant legislations. These policies and legislations provide a long-term goal or vision regarding energy, environment or transportation, outlining what is required, what changes will occur, and the timeline for these changes, without necessarily detailing how these regulations or policies will be implemented. Another remark worth noting is that many of the above mentioned policies and legislations do not explicitly refer to electric motorcycles (or similar terms). Instead, they often use broader terms (e.g., electric road vehicles) or specifically refer to cars (e.g., battery electric cars). While it is reasonable to assume that electric motorcycles fall under the umbrella of electric vehicles whenever addressed in policies and legislations, if this proves not to be the case, then additional barriers might arise in the development of scaled-up projects such as the one assessed in this study. Another remark refers to the fact that there are ongoing discussions regarding a proposed ban on motorbikes within Hanoi's inner city by 2030. Identified references to this potential ban only mention "motorcycles", without specific possible differentiation for electric motorcycles. Should this ban materialise, it could jeopardise the feasibility of electric moped projects.
Effect on climate	Effect on GHG emissions	The use of e-mopeds results in a theoretical reduction in monthly average CO2 (greenhouse gas (GHG)) emissions of 32 kg WTW. The total pilot has a theoretical CO2 reduction of 193 kg WTW. This theoretical reduction in GHG emissions comes from passengers switch from taking the shuttle bus to the e-mopeds. When there is an actual reduction in shuttle km (e.g. shuttle rides are reduced), only then there is a substitution of vehicle km and actual reduction of GHG emissions. Since there is no indication of a reduction in shuttle rides or kilometres, the effect on climate remains potential. The scale up (50 routes) takes into account that there is a passenger km substitution which results in 616 tons of CO2 reduction WTW.
Effect on environment	Effects on air pollutants	Following the reasoning of theoretical and actual substitution of vehicle km, the pilot results in a theoretical reduction in air pollutants of 975 grams NOx and 17.7 grams PM10. The scale up (50 routes) results in a substitution of vehicle km and results in a reduction of 3.1 tons of NOx and 56.3 kg of PM10.
Effect on society	Effects on traffic safety	A shift from two-wheelers to public transport on the road results in higher traffic safety. Given that the pilot results in more two-wheeler km's, and also overall vehicle km, given that the shuttle is assumed to be driving its regular service, results in lower traffic safety. The effect is expected to be minor, given the relatively low amount of kms driven by the e-mopeds in the pilot. The scale up assumes a lot more two-wheeler kms, and although there is a substitution of vehicle kms, will result in lower traffic safety.
	Effects on charging safety	The effect on charging safety in the pilot and the scale-up is hard to gauge, but the risk is assumed to increase given that more charging infrastructure will be required and no dedicated e-moped charging safety standards exist in Vietnam. However, this risk is expected to be mitigated in the future as charging service providers already exist and standards for electric vehicles in general are available.

HIGH LEVEL KPI	LOWER LEVEL PI	FINDINGS
Effect on society	Effects on accessibility	The **accessibility** improvement for society is expected to be minimal as the e-mopeds must travel between stations, which are placed at existing boarding locations for the shuttle. The network is therefore not extended. However, as the e-moped fleet is assumed to be large enough to accommodate travellers immediately, the **travel time** is expected to decrease due to the lack of waiting time.
	Effects on affordability	On the **affordability** side the effects are partially unknown as the pilot offered the e-mopeds free of charge and the Mall subsidizes the current shuttles. If the subsidy is applied to the e-mopeds at the different sites the affordability for the traveller will stay the same at best, but is not expected to improve as the shuttles are already free.
	Effects on security	The **effect on security** was evaluated using the estimated annual number of motorbike theft incidents. There was no reliable source with available data directly from Vietnam, so benchmarks from neighbouring countries were used for comparison and calculation a proxy for Vietnam's motorcycle theft rate (as a percentage of motorcycle stock). The total number of e-mopeds involved in the scaled-up project (5,000) is minimal in comparison to Vietnam's total stock of motorcycles (estimated to be around 72 million by 2020), only a few dozen additional motorcycles are expected to be stolen as a result of the scaled-up project. Due to a lack of specific data, it was estimated that e-mopeds and conventional motorcycles share the same percentage of motorcycle theft (as a share of motorcycle stock) of 0.08%. However, it is reasonable to expect that e-mopeds might get stolen more frequently than conventional motorcycles, since stolen electric motorcycles can be sold or disassembled for parts at a higher profit than conventional ones.
	Effects on service quality	**Service quality** is expected to increase, based on the survey results from the ex-post assessment. The travellers particularly appreciated the improved comfort, driveability and journey continuity in the pilot. The weather suitability and perceived safety of the e-mopeds was scored less favourable than the other topics, but neutral to slightly positive with respect to the current shuttle service.
Effect on wider economy	Effects on national budget	Following the reasoning of theoretical and actual substitution of vehicle km, the pilot results in a theoretical reduction in **air pollutants** of 975 grams NOx and 17.7 grams PM10. The scale up (50 routes) results in a substitution of vehicle km and results in a reduction of 3.1 tons of NOx and 56.3 kg of PM_{10}.
	Effects on employment	Regarding the **effect on employment**, the scaled-up project is expected to generate a job surplus of 450 jobs when accounting also for the effect of potential job losses in conventional shuttle services (affected by a larger-scale introduction of e-mopeds). Although the overall effect on employment is positive, when compared against Vietnam's total labour force (estimated at approximately 55.7 million people in 2022lxi), the projected impact remains marginal.

Recommendations

For future work on the implementation of e-mopeds in Hanoi the authors would like to make a few recommendations, both on the implementation and on the assessment of the process.

- The nature of e-mopeds, especially in the current implementation is rather local: shuttle routes of a few km's are being targeted, travel times are around minutes. However, the current assessment has a very wide scope that targets changes on a national level. While this is understandable from a policy point of view, the effect becomes rather negligible when looking at that level. The effect on a local level could be very pronounced, but when zooming out to the level of a city or a country the effects are diluted. The recommendation is to steer future assessments towards a local approach (on neighbourhood or district level) where each shuttle route is assessed separately, as small changes in the shuttle route can have an impact on the effectiveness of the e-moped service.
- On the implementation itself the recommendation is to investigate if e-mopeds can replace other modes of transport than the shuttle. By focussing on shuttles, which are a relatively safe mode of transport, the improvement is less pronounced as the reduction in safety offsets the reductions in emissions. If however, fossil fuelled mopeds would be targeted for replacement by e-mopeds, the reduced emissions are not offset and the net gain is higher. Finally, the roll-out proved to be challenging due to issues in finding a partner for setting up the IoT devices on the mopeds such that users could rent them via an app. Before further roll-out the focus should be shifted towards getting one site fully operational and user friendly before replication to other sites.
- On the assessment process, the collaboration for a European knowledge institute with local stakeholders proved difficult due to differences in approach and physical distance. The recommendation is to give a local knowledge institute a prominent, leading role in such an assessment as they are better aware of local processes and know how to approach stakeholders effectively. External institutes (from other countries) could be involved, but perhaps only for a few consulting and knowledge exchange sessions.
- Sensibility should also be taken into account when building further on the current assessment. Most KPI calculations are very sensitive to the initial assumptions. While those assumptions are valid for the demo pilot site, it is hard to validate them when scaling up to many different sites. It is recommended to approach each site separately in a future assessment or apply certain categorization such that assumptions can be used for similar sites.

3.2. THE PASIG DEMONSTRATION

The City of Pasig is comprised of 3,434 hectares of 30 barangays in Metro Manila, Philippines. Similar to other cities in the country, Pasig City is experiencing rapid economic growth resulting in higher mobility accompanied by a sharper rise in air quality degradation. Local government units are seen as models of change in adapting to problems of both transportation and climate change. Addressing challenges in these areas requires innovations seen at the city government level to demonstrate possible solutions to the common experiences of poor air quality and rising mobility needs.

Demonstration project: Electric Vehicle Sharing System

The demonstration project for Pasig City focuses on the concept of an "EV sharing system" where SOLUTIONSplus' new and innovative e-mobility solutions can be seamlessly integrated into the Pasig City Government's current vehicle fleet with the objective of optimizing daily operations and maximizing usage. Three complementary solutions are presented: (1) e-quadricycles developed by Tojo Motors for the delivery of medical supplies and personnel, (2) charging solutions, and (3) an IT booking application to manage the operations of these e-quadricycles and other e-mobility vehicles of the city government.

The e-quadricycles are compared directly to the city government's existing internal combustion all-purpose vehicle (hereinafter, APV), currently used for transporting medical supplies and personnel. Various indicators are considered to assess the potential impact of the e-quadricycles on the city government, including environmental (noise, air quality), social (quality of service, accessibility, safety, security), institutional or political (policy), and financial (affordability) indicators.

Financial indicators

Affordability and financial sustainability are key considerations in adopting new e-mobility solutions. The ex-ante assessment shows that there is available financing for government-owned electric vehicles from city and national government funds as well as from the Pasig City Government's numerous partnerships with international organizations.

Because the e-quadricycles are government-owned and operated, there is no assessment of their commercial viability. However, using government funds to acquire and operate these vehicles asks for a study on the financial costs to the city government using a Cost-Effectiveness Ratio (CER).

The CER assesses the APV and compares it to the e-quadricycle. When considering the CER per passenger kilometres travelled (PKT), freight-ton kilometres (FTK) travelled, and vehicle kilometres travelled (VKT) on an annual basis, the e-quadricycle is easily more cost effective than the APV. While these comparisons are based on different daily kilometres travelled (35km/day for e-quadricycle and 40km/day for the Suzuki APV), it is important to note that the e-quadricycles are still in its pilot phase and not completely optimized in the city's operations. Once maximized, the e-quadricycle is expected to perform even better.

Table 7: Comparison of the new with the old solution in terms of CER

COST-EFFECTIVENESS RATIO (CER) CATEGORIES	OLD SOLUTION (APV)	NEW SOLUTION (E-QUADRICYCLE)	
		CURRENT USE (35KM/DAY)	OPTIMAL USE (40KM/DAY)
CER-VKT	75.07 pesos/vkt	55.76 pesos/vkt	48.79 pesos/vkt
CER-PKT	10.72 pesos/pkt	9.29 pesos/pkt	8.13 pesos/pkt
CER-FTK	125.11 pesos/ftk	113.80 pesos/ftk	99.58 pesos/ftk

Environmental indicators

The e-quadricycles are seen to improve overall environmental quality when compared to the APV. E-quadricycle emission is merely 70.11 gCO2/km and 0.44 MT CO2/year compared to the APV which emits 428.57 gCO2/km and 2.67 MT CO2/year, resulting in the e-quad mitigating about 2.24 MT CO2/year of GHG emissions.

The e-quadricycles are expected to slightly reduce the amount of PM2.5 and CO emissions compared with the Suzuki APV. Per e-quadricycle, the expected abated PM2.5 yearly is 0.0686 kg while the expected abated CO emissions yearly is 12.54kg.

Table 7: Comparison of the new with the old solution in terms of CER

VEHICLE	GHG (GCO2/KM)	GHG (MT CO2/YEAR)	NOX (GNOX/KM)
ICE APV	428.57	2.67	0.064
E-quadricycle	70.11	0.44	0.000

In addition to the assessment of air-quality, the e-quadricycle's impact on noise is also compared to the APV. Professional Pasig City drivers from the Pasig City Health Department reported that the e-quadricycles would make a screeching sound when running at 20-30kph and there would be a humming noise coming from the e-quadricycles' motors. However, the drivers still assessed that the e-quadricycles are "significantly quieter" than the APV.

Social indicators

On the impact on road safety of the e-quadricycles, the professional drivers reported that there was a positive effect on the road safety situation in the city, due to the restricted speed of the e-quadricycle and its light frame. Likewise, the e-quadricycles are also expected to have minimal impact on charging safety (such as electric shock and fire hazards) primarily due to the external environmental protections on the charging stations and strict adherence to existing Philippine codes and policies on charging infrastructure.

However, when compared to the APV on quality of services, professional Pasig City Government drivers assessed the APV to perform better than the e-quadricycles on suitability to adverse weather conditions, perceived comfort in travel, ease of charging/refueling, and personal security. On the other hand, professional Pasig City government drivers reported that the e-quadricycles performed better than the APV on ease of driving, safety within the city, and continuity of journey chains.

Institutional/political indicators

The transition to integrating e-quadricycles are aligned with national and regional initiatives on e-mobility. The demonstration supports policies in transportation (National Transportation Plan, Electric Vehicle Industry Development Act (EVIDA), Comprehensive Roadmap for the Electric Vehicle Industry - CREVI), energy (Philippine Energy Plan, Energy Efficiency Conservation Act, Alternative Fuels and Energy Roadmap), environment (Philippine Environment Code), and other overarching policies (Nationally Determined Contributions).

Because of ongoing changes in the regulations of electric vehicles in the Philippines, it cannot yet be ascertained how compliant the e-quad is to national or city regulations. The EVIDA and CREVI have yet to consolidate standards for some e-mobility such as e-quadricycles. Additionally, although the Land Transportation Authority established their own registration and regulation processes, city governments can still mandate their own interpretations and implementations of standards that suit their cities' respective contexts.

Moreover, the new technology has yet to gain full support from existing political and institutional bodies. It is hoped that this demonstration will present e-quadricycles and its accompanying shared EV system as viable solutions to addressing the pressing challenges of environment-friendly mobility around Philippine cities.

Scaled-up scenarios

Given the current and past investment of the City Government of Pasig on e-mobility and the overall environmental, financial, and social benefits of the e-quadricycle compared to the currently mainstreamed APV, there is sufficient need to evaluate the scale-up of the city's e-quadricycles and its integration into public transport potentially replacing ICE tricycles. Three different scale-up scenarios were studied: (1) 100 new e-quadricycles will be added to the existing Pasig LGU fleet by 2025 (Scenario 1), (2) new e-quadricycles will accommodate the increased EV demand of 1.3% and half of Pasig City public transport three-wheelers will be electrified (Scenario 2), and (3) new e-quadricycles will accommodate the increased EV demand of 1.3% and all of the city's public transport three-wheelers will be fully electric (Scenario 3).

The three scenarios were compared to the business-as-usual or baseline situation of Pasig City. Scenario 1 is assessed to have almost similar projected MT CO2 emissions as the baseline assessment by 2040, at around 26,000 MT CO2 emissions. This is significantly higher than Scenario 2 at (22,500 MT CO2) and Scenario 3 (20,000 MT CO2) by 2040. Scenario 3 has double the avoided MT CO2 emissions for 2040 compared to Scenario 2, and almost seven times more than Scenario 1.

3.3. THE KATHMANDU DEMONSTRATION

This section presents the work performed by the SOLUTIONSplus consortium for the impact assessment task of the Kathmandu demonstration project. All vehicles of the Kathmandu demo have been assessed. For the four vehicles that either have not been completed by the time of drafting this report or have been completed but not licensed yet, the assessment is restricted to the ex ante one.

3.3.1. Assessment of the Kathmandu demonstration project

Motivation and objectives

With growing urbanisation and income, the demand for private vehicles in Kathmandu increases fast also straining the available public transport services in the city. Adverse effects are observed in several directions, including congestion, air pollution, GHG emissions, and service quality attributes such as frequency of service, safety, and comfort.

The Kathmandu demonstration action of the project aims to contribute to creating an ecosystem of electric mobility in the valley to enhance public transport. It includes the following components:

- **Converted bus.** An old diesel mini-bus has been converted to an e-bus, mainly through replacing the drive system (motor, transmission, and rear axle) with imported components, while assembly will take place locally.
- **Remodelled Safa Tempo for passengers.** Safa tempos are electric 3Ws built in late 1990s for passenger transport. Remodelling included the replacement of the old lead acid battery set with a 23 kWh Li-ion battery, and the upgrading of the passenger cabin to make riding more comfortable.
- **Remodelled Safa Tempo for cargo.** A remodelled Safa tempo demonstrates the possibility of expanding the vehicle's utility to freight transport while replacing a conventional ICE pick-up truck.
- **New e3W design for passengers.** A mini Safa Tempo (6-seater) modular e3W design, easily customised to a passenger, cargo, or waste collection operation is to be developed. The passenger version was not completed by the time of drafting this report.
- **New e3W design for cargo.** Same vehicle with the previous one, customised for cargo operation. The prototype has been completed but not licensed yet.
- **Converted e4W design for waste collection.** The waste collection version of the previous design proved financially infeasible and was replaced by a converted 4W pick-up truck especially adjusted for the intended operation. However, the converted truck was not completed by the time of drafting this report.
- **Converted pick-up truck.** Aims to replace the widely used ICE pick-up truck with an electric vehicle.
- **New e-shuttle van design.** A closed-type van for 6 passengers suitable for transporting tourists to the Bhaktapur historical sites. This vehicle was not completed by the time of drafting this report.
- **Prefeasibility of a MaaS application.** Preliminary study of the potential introduction of a MaaS application in Kathmandu offering smart fleet management services including an integrated electronic payment system.

User needs analysis

With 16 responses to our online survey and 15 interviews with stakeholders in Kathmandu, the user needs analysis succeeded in obtaining the necessary feedback. The stakeholders have validated the design of the Kathmandu demo, which is seen as pivotal in developing an e-mobility ecosystem in the city. The bus conversion can become a valuable option for reducing the capital cost of e-mobility in this sector if proven financially and technically feasible. The conversion/remodelling of smaller vehicles also exhibit substantial potential in transforming urban transport. These initiatives have already contributed to the necessary regulatory reform that took place during project lifetime on legalising conversion activities. On the negative side, the width of demo activities (eight different vehicle components and a prefeasibility analysis on a MaaS application) proved a large-scale task stressing the available resources.

Stakeholder priorities

Two rounds of feedback solicitation have been undertaken in relation to stakeholder priorities (KPI weights). Among the findings, the following are worth noting: (i) the significant weight of 'availability of finance,' probably indicating the need to provide low-interest loans to support the relatively high initial investments required, (ii) the significant weight of 'ease of implementation,' indicating the existence of administrative barriers, and (iii) the highest priority placed on 'affordability' among all societal indicators examined (missing from the summary table below, since it was later dropped as irrelevant).

Table 9. Weights and scores of all KPIs entering the assessment of the Kathmandu demonstration project

Code	KPIs participating in the assessment	KPI weight		Converted bus	Remodelled e3W pax	Remodelled e3W cargo	New e3W design pax	New e3W design cargo	Converted e4W waste	Converted truck	New e-shuttle van
		Absolute	Normalised	KPI score (or attribute value that needs to be transformed into a star value through a value function)							
	Required investment (EURO per unit)			46.235	13.760	13.760	8.115	9.950	14.465	13.600	17.820
A1.	Financial viability	0,122452	0,151963	IRR=14,86%	IRR=57,81%	IRR=59,06%	IRR=30,58%	IRR=87,93%	ΔCER=-13,52%	IRR=63,87%	ΔCER=-64,09%
				3	5	5	5	5	4	5	5
A2.	Availability of financial resources	0,111906	0,138875	3	5	2	5	2	2	2	3
B1.	Coherence with national plans	0,058573	0,072689	5	5	5	5	5	5	5	5
B2.	Alignment with legislation	0,054022	0,067041	2	2	3	2	3	2	2	3
B3.	Ease of implementation	0,063906	0,079307	3	3	3	3	3	3	3	3
C1.	Effect on GHG emissions (tonnes/year/unit)	0,131929	0,163724	-15,14	0,00	-5,78	0,00	-5,78	-4,00	-5,78	-15,09
D1.	Effect on NOx emissions (kg/year/unit)	0,028315	0,035140	-201,30	0,00	-26,49	0,00	-26,49	-18,35	-26,49	-70,75
D2.	Effect on PM2.5 emissions (kg/year/unit)	0,035386	0,043915	-52,00	0,00	-36,42	0,00	-36,42	-25,23	-36,42	-24,19
D3.	Effect on noise	0,042560	0,052817	5	3,86	5	3			5	
D4.	Effect on environmental resources	0,048381	0,060041	5	5	5	1	1	5	5	1
E6.	Effect on major accidents	0,006757	0,008385	4	3	3	3	3	4	4	4
E7.	Effect on minor accidents	0,004625	0,005740	4	3	3	3	3	4	4	4
E8.	Effect on vulnerable road users	0,004662	0,005786	3	3	3	3	3	3	3	3
E9.	Effect on charging safety incidents	0,017880	0,022189	2	3	3	3	3	2	2	3
E10.	Effect on security incidents	0,012324	0,015295	3	3	3	3	3	3	3	3
E12.	Suitability for adverse weather	0,002225	0,002761		3,69	3					
E13.	Perceived comfort	0,002562	0,003179	4	4,09	2				3	
E14.	Perceived drivability (prof. drivers)	0,002168	0,002690	4	4,50	5				5	
E16.	Perceived chargeability	0,003002	0,003725	2	4,50	2				2	
E17.	Perceived safety	0,002739	0,003400	4,50	3,70	2				3	
E18.	Perceived personal security	0,002306	0,002862		3,53	3					
F4.	Effect on jobs (net jobs per unit produced)	0,026421	0,032789	0,6381	0,4000	0,4000	0,6667	0,6667	0,6667	0,6000	0,6952
F5.	Effect on technical skills (net EV technician equivalent positions per unit produced)	0,020699	0,025688	0,6466	0,4545	0,4545	0,7760	0,7605	0,7605	0,7157	0,8271
	Total	0,805799	1,000000								
	Not available pending completion of ex post assessment										

Financial viability

The financial results are promising, with all vehicles achieving top score, except for the converted bus and the waste collector (with a score of 3 and 4 respectively in an 1-5 scale). For the six revenue-earning components, IRR ranges from 14.86% (converted bus) to 87.53% (new e3W design cargo). Both non-revenue-earning components exhibit significant reductions in the CER values, although care should be taken to verify these results in practice, as they are very sensitive to the actual transport work performed (volume of waste collected and passengers carried respectively).

In general, the profitability of the freight vehicles appears more robust, with IRRs above 59%. With an IRR of 14,86%, the converted bus achieves similar returns to those of a new e-bus, with less than 65% of the investment requirements. To achieve the economies of scale considered in the analysis (mostly concerning the purchase price of the imported conversion kits), a sufficiently large number of conversion projects is needed. The conversion/remodelling of lighter vehicles in operation is also profitable. However, so are the old fossil-fuel-driven solutions, depriving operators of running vehicles from sufficient motivation to convert. As such, conversions at scale can be expected only at the end of the useful lives of existing vehicles.

Availability of financial resources

The scores on this indicator range between 2 and 5. The highest score is achieved by the remodelled and newly designed e3W for passenger services due to the possibility of obtaining entrepreneurship loans offered by commercial banks to female owners of such vehicles.

Institutional issues

All components are fully coherent with the national plans and development goals. The common uncertainties that all components face relate to the lack of technical standards and working guidelines/directives that convert the national strategies to specific actions. Investments in light public transport passenger vehicles are challenged by the remnants of the syndicate system that has been formally abolished. In terms of implementation, although the necessary political and institutional bodies are in place, the frequent changes and transfer of officials at the relevant government offices slow the process.

Climate change and environmental aspects

All demo vehicles demonstrate significant emission reduction potential, except for the passenger 3Ws, intended to replace the aging electric Safa Tempo fleet. In relation to environmental resources, the converted and remodelled vehicles achieve a high score due to the remanufacturing activities and the opportunities for recycling that they offer. On the contrary, the new designs score low as the manufacturing processes still rely on conventional practices and the vehicles lack smart features that could contribute to more efficient and sustainable operations. Battery recycling needs to be pursued at national level, as presently there is no such infrastructure, and batteries are either improperly dumped or exported to India.

Road safety

The three indicators concerning road safety were assessed through interviews with five transport experts. No distinction was made between major and minor accidents. For these two KPIs, the converted vehicles (bus and trucks) are expected to lead to a slight improvement over the old solutions due to lower probability of mechanical failures. No change is expected for the e3Ws, while the shuttle van lies in between. In relation to accidents involving VRUs, none of the demo vehicles is expected to have an influence on average, as one of the experts anticipates improvement due to the better drivability of EVs, one expects deterioration due to their lower intensity noise, while the others see no foreseeable change.

Charging safety

The risk of accidents related to the charging of EVs is expected to grow with the proliferation of e-mobility. The lack of institutionalised standards in the country can aggravate this risk. The formal standardisation of the locally produced EVs is expected to reduce this risk in addition to facilitating consumer trust. Electrical shock exhibits the highest risk for the converted and remodelled vehicles, as these vehicles may be more prone to equipment malfunctions or human errors during maintenance/repairs. The new designs are expected to suffer more by instability in the power grid, which, despite minor/low impact, occurs frequently in Nepal due to intermittent power supply and voltage fluctuations.

Security issues

The security challenges are driven mostly by exogenous factors such as the socio-economic conditions, political environment, and geographical aspects rather than the type of vehicles. The security risks concerning passenger vehicles are much higher than those of the freight ones. However, when the experts were asked to compare the new solutions with the corresponding old ones, they were not able to detect a difference, giving the same score to all demo components.

Effect on employment

Experiences in both Nepal and other countries suggest a significant effect on job creation associated with EV manufacturing. Following the successful implementation of the Global Resources Institute electric vehicle programme in Kathmandu during 1993-1996, five different manufacturers produced a total of 706 Safa Tempos during 1996-2011, an average of 47 a year. The new vehicle designs are expected to have the highest impact in this respect.

Scaled-up project

Given that all five of the demo vehicles that fall under the private sector (the four e3Ws and the converted pick-up truck) exhibit healthy financial returns, no subsidies are required for their promotion. Regarding these vehicles, therefore, the scaled-up project includes only support activities (monitoring the prototypes' operation to verify their technical and financial viability, informing commercial banks about potential targeted loan schemes, and undertaking awareness campaigns targeting potential investors and operators). An optimisation exercise has been undertaken concerning the remaining three vehicles. For a budget of € 2 million, a fleet of 25 buses, 20 waste collectors and 30 shuttle vans exhibits the best performance in meeting the stakeholder priorities. If the Lalitpur municipality wishes to exclude the shuttle vans, which are targeted to the tourist industry, the optimal fleet becomes 40 buses and 10 waste collectors.

Prefeasibility of a MaaS application

Despite great potential, the establishment of a MaaS platform in Kathmandu was found presently premature due to the lack of a properly functioning public transport system. Quality improvements in this regard will probably require a different business model incentivising all actors involved and supported by a suitable regulatory framework. Once a framework of fixed routes/schedules/fares is put in place, an ITS platform can be introduced initially covering all buses, later followed by 3Ws. E-ticketing is suggested for the second stage of development, provided that reliable hard/software is put in place and disincentives to drivers and conductors associated with hidden cash earnings are eliminated.

3.3.2. The assessment methodology

The assessment framework covered all relevant aspects. A gap identified by the EU Project Officer relates to the suitability of the vehicles to serve disabled passengers. Although not formally assessed through a specific KPI, this aspect was considered in the service quality questionnaires soliciting stakeholder perceptions.

Out of the 34 KPIs of the framework, only 23 were finally considered for the Kathmandu demo. The exclusion of criteria took place in four different stages of the assessment process:

a. At the first stakeholder workshop, the following three KPIs were considered irrelevant for the Kathmandu demo and excluded from the value function development:
    - Effect on accessibility – passengers (E1)
    - Effect on well-being through active travelling (E11)
    - Effect on drivability as perceived by end users (E15)
b. Five more KPIs turned out to be irrelevant after obtaining information from the end users, drivers, and experts:
    - Effect on accessibility – freight (E2)
    - Effect on affordability (E3)
    - Effect on travel time – passengers (E4)
    - Effect on travel time – freight (E5)
    - Effect on transhipment quality (E19)
c. Another two KPIs were dropped due to difficulties in obtaining the necessary data:
    - Effect on budget (F1)
    - Effect on other imports (F3)
d. One more KPI was finally dropped due to a great deal of overlap with the emission-related indicators, when viewed outside the external trade context:
    - Effect on fossil fuel imports (F2)

In terms of weight, the 23 indicators entering the Kathmandu assessment account for 80.58% of the total. Furthermore, it is worth noting that 7 of these indicators made no difference in selecting the optimal scaled-up project, as identical scores were given to all three vehicles of the scaled-up project. These KPIs were:

- Coherence with national plans (B1)
- Ease of implementation (B3)
- Effect on major accidents (E6)
- Effect on minor accidents (E7)
- Effect on vulnerable road users (E8)
- Effect on security incidents (E10)
- Perceived personal security (E18)

It can then be argued that the range of KPIs in the assessment framework is overly ambitious and could have been reduced. Although this is certainly a possibility, one needs to consider that the framework was designed to deal with a variety of interventions that might be very different in nature than those demonstrated in Kathmandu.

A related issue concerns the definition of KPIs and the associated data requirements. For two indicators (F1 and F3), this became an issue, and the city team was unable to conceive an alternative formulation based on available data. Dropping these attributes became necessary.

Value functions is also a rather sensitive issue as they can have a significant effect on the star values. On one hand, they should be designed to differentiate sufficiently among the alternative solutions examined. On the other, a prior knowledge of the alternative solutions might permit strategic responses. A balance needs to be achieved by the moderator of the stakeholder meeting.

Another concern relates to the reliability of several of the KPI values, which depend on the skills and experiences of the individuals that provide the necessary input. This is an inherent characteristic of the MCDA techniques, which are used for assisting stakeholders reach better decisions according to their own set of values, visions, and priorities. In this respect, the suggested scaled-up project is basically the result of the collective input of all these stakeholders who kindly provided input in relation to the KPI weights, KPI scores and value functions.

Notwithstanding the limitations mentioned above, the framework as applied in the Kathmandu demo produced the expected results. In addition to formulating the scaled-up scenario, the ex ante assessment played a critical role in the design of the demo vehicles, ensuring through several iterations that the design is compatible with financially sound operational profiles.

The timing of the assessment activities proved challenging; a rather usual occurrence given that ex post assessments cannot be performed prior to the delivery of the prototypes. The high number of demo components contributed to this challenge.

In terms of the tools used in the assessment, FMC proved effective, flexible (application-specific values can be used in addition to default ones), and user-friendly as the model is well-documented. Among the metaheuristics deployed in the optimisation exercise, the less popular Grey Wolf Optimiser outperformed the other two algorithms in terms of both effectiveness and efficiency.

3.4. THE KIGALI DEMONSTRATION

This section details the activities carried out by the SOLUTIONSplus project to assess the effect of the Kigali demonstration action.

Motivation and objectives

In Kigali, with rapid urbanisation and growth in income, the demand for private vehicles increases, straining the city's available public transport services in the city and causing several externalities.

The SOLUTIONSplus demonstration action supports various forms of electric mobility to address the main mobility and transportation-related problems identified in the city. The first component focuses on electric mobility for last-mile connectivity, in the form of light electric two-wheeled vehicles. The demonstration project supports electric motorcycle taxis, used for commercial services (taxi), and shared pedal-assist electric bicycles. Completing this activity on light electric vehicles, the project decisively supported the transition to electric public transport through a pilot of electric buses, aimed at collecting data and supporting the development of a Kigali E-Bus Master Plan. The project provides financial and technical support to selected companies, as well as policy and regulatory advice to public authorities, including institutional support via the creation of the E-Mobility Technical Committee.

Electric motorcycles: The project supported the development of robust electric motorcycles, with vehicles and batteries locally designed and assembled, an innovative re-energising model of battery swapping adapted to local needs and conditions, and technical support for scale and industrialisation. 24 e-motos were supported through the project. In addition, the project proactively used the transition to increase the involvement of women in the provision of transport services, by handing over the e-motos to trained women and sharing learnings and recommendations to a large regional and international audience.

Electric bicycles: To facilitate the integration of feeder services with the public transport system, a bike share system with 80 conventional bicycles was deployed on two corridors connecting to bus stations in 2021, with the aim to introduce pedal-assist electric bicycles in the shared fleet. 50 electric bicycles were planned to be introduced, but the implementation is delayed due to various company and ecosystem-based challenges described in this document.

Electric buses: A pilot enabled the introduction of four electric buses in December 2023, with an innovative leasing model helping operators face current challenges in accessing rolling stock. This pilot provided input into the E-Bus Charging Master Plan initiated by the City of Kigali and ITDP in the second half of 2023. The master plan will focus on establishing the electric energy required to charge the fleet for the pilot e-buses, the location and technology of the chargers, the set of routes and the most suitable business models for the city.

Policy and institutional e-mobility framework: The City of Kigali initiated the E-mobility Technical Coordination Committee as part of SOLUTIONSplus, providing a well-recognised platform for information sharing and alignment between public and private organisations. SOLUTIONSplus provided multidimensional policy support to deploy an EV charging infrastructure, recommendations for fiscal conditions for pedal-assist electric bicycles, and a city roadmap on electric mobility. Planning support was provided by the Technical University of Berlin through a Design Studio in 2022 and 2023, focusing on the development of three speculative design solutions for public transportation, e-mobility, and road safety.

User needs analysis

With 6 responses to our online survey and 9 interviews with stakeholders in Kigali, the user needs analysis succeeded in obtaining the necessary feedback. Stakeholders were grouped into public/paratransit companies; national, regional, and local authorities; passengers and individual travellers; service providers; OEMs, associations, importers, and exporters; academic and research organisations; and finally, foundations and funders.

Stakeholder priorities

Among the findings, the following are worth noting: (i) the highest priorities were given to the impact the demonstration will have on climate and the environment, (ii) the next highest priority was allocated to available finance and financial viability of the projects (iii) the third highest priority was allocated to effect on institutional frameworks, where the ease of implementation of the project was accorded a very high priority.

Table 10. KPI weights and scores for the Kigali demo

KPI DEFINED WITH STAKEHOLDER INPUT	ENTERING INTO EVALUATION	ABSOLUTE WEIGHT	NORMALISED WEIGHT	KPI SCORE		SCALE
				E-MOTOS	E-BICYCLES*	
A1. IRR (Internal Rate of Return)		8.70	11.06	17.48%		%
A2. Ease of raising external funding		9.00	11.44	3.5	3.5	5 point
B1. Coherence with national plans/goals		5.48	6.97	4.50	5	5 point
B2. Alignment with legislation		3.91	4.97	3	3	5 point
B3. Ease of implementation		6.01	7.64	5	5	5 point
C1. Effect on GHG emissions		18.40	23.39	71.80%		%
D1. Effect on NOx emissions		3.75	4.77	100.00%		%
D2. Effect on PM2.5 emissions		3.81	4.84	100.00%		%
D3. Effect on noise	No	5.69	0			
D4. Effect on recycled resources		5.25	6.68	3.50	3.5	5 point
E1. Effect on accessibility (passengers)		1.92	2.44	3	4.5	5 point
E2. Effect on affordability		2.16	2.75	3.00		5 point
E3. Effect on travel time (passengers)		2.04	2.59	3.5		5 point
E4. Effect on major accidents (road safety in general)		0.81	1.03	3		5 point

KPI DEFINED WITH STAKE-HOLDER INPUT	ENTER-ING INTO EVALUA-TION	ABSO-LUTE WEIGHT	NOR-MALISED WEIGHT	KPI SCORE		SCALE
				E-MOTOS	E-BICY-CLES*	
E5. Effect on minor accidents (sverity of road accidents)		0.50	0.64	3		5 point
E6. Effect on near ac-cidents (road safety of vulnerable groups)		0.56	0.71	4		5 point
E7. Effect on charging safety incidents	No	1.50	0			
E8. Effect on security incidents	No	1.56	0			
E9. Effect on well-being (active travel)		1.94	2.47	3		5 point
E10. Suitability for climate changes		0.40	0.51	3.21		5 point
E11. Perceived comfort		0.25	0.32	2.93		5 point
E12. Perceived drivability (prof. drivers)	No	0.27	0.34			
E13. Perceived drivability (end users)	No	0.25	0.32			
E14. Perceived charge-ability		0.28	0.36			
E15. Perceived safety		0.26	0.33	2.98		5 point
E16. Perceived personal security		0.24	0.31	3.19		5 point
E17. Perceived tranship-ment quality	No	0.27	0.34			
F1. Effect on budget	No	5.02	0			
F2. Effect on fossil fuel imports		2.98	3.79	4%		%
F3. Effect on other imports	No	2.19	0			
F4. Effect on jobs	No	2.24	0			
F5. Effect on wages	No	2.38	0			

*All KPI cells in yellow could not be evaluated since the demonstration could not take place during project implementation period

Financial viability

For the e-motos, the company provides the e-motos to the drivers at a unity cost of USD 1,284 in 2021, available through various financial models such as lease-to-own, rental or outright purchase. The company owns the batteries and provides the charged batteries and uses a battery-swapping model. The drivers pay a charging price of 1.84 USD per charge as of 2021. The company did not provide information on their capital and operating costs for operating the battery swapping system. Therefore, the financial analysis is from the theoretical perspective of a driver achieving the average minimum salary level found in Rwanda. The revenue per day for e-motos is 13.50

USD and after accounting for all costs she can earn a net revenue of 1.11 USD. The pretax internal rate of return is 42%, which can be considered very good from drivers' perspective.

Availability of financial resources

The score for this indicator for both e-motos and e-bicycles was 3.3. There were mixed responses to the question on the availability of government funds to support the project for both interventions, but all the stakeholders felt that international donors strongly intended to fund similar projects. More stakeholders felt that the commercial bank was not yet prepared to support such initiatives, especially the e-moto intervention.

Institutional issues

Both interventions are fully coherent with the national and sub-national policies and development goals, that is the Government of Rwanda's program to retrofit electric motorcycles and National Transport Policy and Strategy, 2021. Likewise, they are also fully aligned with the city level plans and policies to enhance the last mile connectivity. There was a lack of clarity as to whether the interventions were fully consistent and aligned with environment policies at the national level, as the stakeholders gave a mixed response here. Overall, all the stakeholders felt that the interventions were fully aligned with the energy and transport policies at the national level and city level policies, and with the overarching policies at the national level like the National Development Plans, Climate Action Plans, NDCs etc.

Alignment with supra-national/national/city legislation & regulations was a bit more uncertain compared to alignment with national plans and development goals. Both e-motos and e-bicycles are fully compliant with the vehicle standards and regulations; however, as the electric vehicle policy is not detailed, alignment to electric vehicle standards and charging infrastructure standards was a bit uncertain. Likewise, alignment with charging operations, user-consumer protection (for electric vehicles) and environmental regulations was also a bit uncertain.

All the stakeholders opined that both e-motos and e-bicycles projects face no administrative barriers as the institutional bodies are in place, policies are in place or are being formed, and, most importantly, the government has strong buy-in for the projects. However, e-bicycles do face relatively higher financial barriers since they are not included in fiscal incentives provided by government for EVs.

Climate change and environmental aspects

In Kigali, as the e-motos (Kigali) replace the old ICE vehicles, they result in a significant GHG emission reduction of 73% from the base case technology in the base year. Over the life span, the CO2 emission reductions will be 71.8% lower in comparison with the ICE-motos. The CO2 reductions from e-buses are even higher than e-motos and 93% lower in comparison with diesel buses in the base year. Likewise, there is also a significant air pollution reduction as these vehicles have no tailpipe emissions. The effect on noise has not been considered in the project, but there is no noise from the e-motos, and their introduction is expected to reduce noise pollution.

Effect on society

As the routes and operation of e-motos remain the same, accessibility levels remain the same; with e-bicycles integrated with public transport, personal accessibility is likely to increase substantially, with 78% population coverage. As the fares don't change, there is no change in the affordability of the end users. As the routes don't change, the effect on travel time is also expected to remain the same. However, most e-motos users felt that travel on e-motos was marginally faster compared to ICE motorcycle, possibly due to higher acceleration and better navigation possibilities compared to traditional ICE engines.

Road safety

Most of the users also felt that changing to e-motos from ICE motorcycles had no impact on the overall safety situation in the city or on an increase or decrease in the severity of road accidents. However, more than half respondents who used e-motos users felt that e-motos significantly increased the safety of vulnerable road users, even though one would expect the opposite because of increase acceleration and no noise from e-motos. This response could be because of the feel-good factor about e-motos, or their having better breaking response. The fact that responses were collected from users who are e-moto enthusiasts can be also responsible for this.

Charging safety

The risk of accidents related to the charging of EVs is expected to grow with the development of e-mobility. The lack of institutionalised standards in the country can aggravate this risk. As batteries are not charged by e-motos drivers or by the end users, this indicator could not be tested in the absence of input from the company.
Effect on service quality

The results show that the e-moto users have rated all the service level indicators a little above average. Users perceive e-motos as more secure, help in the continuity of travel which can be linked to response on journeys taking less time, so they can improve connectivity. Otherwise, there should be no change in the connectivity levels as the routes remain same. The respondents also felt the e-motos help reduce noise levels and are more suitable in adverse weather conditions.

Effect on employment

Inputs from Ampersand providing the motorcycles were requested on the job creation through e-motos. This information was requested for the specialities relating to EVs: (i) EV technicians involved in the construction and mainly maintenance of the vehicles, (ii) battery swapping attendants (iii) EV design engineers involved in the design or remodelling of vehicles, and (iv) IT analysts or other Industry experts. However, no information could be obtained.

Scaled-up project

The National Transport and Policy Strategy for Rwanda (2021) had extremely ambitious targets for EVs (p.49). It targeted 30% of the new vehicles to be electric by 2023/2024, and by 2034/35, 70% could be electric. We have, therefore, considered this as a target for e-motos as well and quantified the impacts of the same on the wider economy, climate, and environment. The e-motos can result in substantial fuel savings from the BAU scenario where motos run on gasoline. However, since motos only account for 8.8% of overall demand for petroleum products the cumulative fuel savings (2020-50) at a national level will be only around 4% of the BAU scenario.

Overall assessment

E-motos being a cleaner alternative to ICE-motos aligned well with user expectations, and the demo has contributed to building momentum for e-motos in Kigali. Ampersand was able to leverage significant funding beyond SOLUTIONSplus for the e-motos. The project has provided positive results with regards to KPIs, pace of uptake of e-motos during the lifetime of SOLUTIONSplus (from about 30 vehicles in 2020 to 1,350 motorcycle taxis and 10 swapping stations as of late 2023). In addition, the project included a successful gender-inclusive component, with 35 women trained as e-moto drivers and 24 female e-moto drivers receiving their electric motorcycles. Challenges remain, such as the facility to recruit trained engineers and mechanics, or the need to complete the regulatory landscape with clear standards and guidelines on the process to deploy charging infrastructure. Yet, the component of e-motos seems to be on a positive path to scale.

The component of e-bicycles is more challenging, as it faced large delays in the roll-out of the demonstration action. These challenges are related to barriers found on the side of the e-mobility company (impact of Covid on supply chains, challenges of Asia-based imports of parts, iterations from the initial model, lack of communication and reporting skills, lack of funding alongside SOLUTIONSplus) and the lack of an enabling environment (regulatory challenges in the partnership between the company and the city, absence of subsidies, pedal-assist electric bicycles not exempted from taxes, unlike larger electric vehicles). SOLUTIONSplus partners are in the process of identifying key learnings and recommendations to suggest pre-conditions for a viable system in the future.

E-bus demonstration took place quite late in the project, so it was not possible to assess the effects on all KPIs. However, despite the late start, the e-bus demo provided inputs for the E-Bus charging Master Plan, and BasisGo, the private entity responsible for the implementation of the demo, is already looking for scaling up and indicates the financial viability of the business model they tested with the 4 e-buses. The climate and environmental impacts of e-buses were quite significant, especially in the initial years when the baseline technology was dominated by older, relatively inefficient and more polluting diesel buses.

3.5 THE DAR ES SALAAM DEMONSTRATION

As part of the SOLUTIONSPLUS project, the feasibility and implementation of electric three-wheelers to support the Bus Rapid Transit (BRT) public transport system in the city of Dar es Salaam was performed. In a contextualised implementation approach, electric three-wheelers that are owned and operated by private persons but perform feeder mode tasks into public transport were developed. In addition, the project supported the introduction of pedal-assist electric bicycles used for urban deliveries, capacity-building activities, policy advice and awareness raising activities. The project spanned 54 months, commencing in 2020 and concluding in June 2024. As part of the project, the project team conducted an Impact Assessment (IA) to evaluate the success of the project. This executive summary presents the major findings of the

IA, including results obtained up to April 2024. It forms part of Deliverable 1.6 of the SOLUTIONSPLUS project.

The IA is based on the assessment of Key Performance Indicators (KPIs), which were defined in Work Package 1 of the SOLUTIONSPLUS project. The KPIs were developed based on inputs from experts. A generic set of KPIs was defined by the project team, however the KPIs were adapted for each pilot city to account for specific contexts. The following table lists the KPIs that were discussed throughout the IA for Dar es Salaam:

Table 11: KPIs entering the Dar es Salaam demo assessment

FINANCIAL INDICATORS	A1	Financial Viability
	A2	WEase of raising external funding
INSTITUTIONAL/POLITICAL INDICATORS	B1	Coherence with national plans and development goals
	B2	Alignment with supra-national/national/city legislation & regulations
	B3	Ease of implementation (in terms of administrative barriers)
CLIMATE-RELATED INDICATORS	C1	Impact on GHG emissions
ENVIRONMENTAL INDICATORS	D1-2	Impact on air pollutants
	D3	Impact on noise
	D4	Impact on environmental resources
SOCIAL INDICATORS	E1	Access to jobs, opportunities, services (personal travel)
	E6	Road accidents with fatalities/serious injuries
	E7	Road accidents with minor injuries/material damage
	E8	Road accidents involving vulnerable road users
		Additional indicators entering the descriptive evaluation
	E9	Impact on charging safety
	E10	Impact on security
		Quality of e-mobility services
WIDER ECONOMIC INDICATORS	F1	Impact on national/local budget
	F2-3	Impact on external trade
	F4-5	Impact on employment

The results of the impact assessment can be summarised as follows:

Electric three-wheelers

In relation to the **financial indicators**, the project demonstrated a positive internal rate of return, indicating that the operation of electric three-wheelers in Dar es Salaam is likely to be profitable. **Institutional and political indicators** were discussed during the validation process. The results indicated that electric three-wheelers are aligned with city goals, but that there are still governance-related barriers that may delay their introduction. **Climate-related indicators** were evaluated using the UNEP eMobility Calculator and primary data on noise, indicating that electric three-wheelers would significantly contribute to reducing climate and local particle and noise emissions and would facilitate resource conservation.

In general, electric three wheelers in Tanzania show emissions that are 76% lower than their internal combustion engine counterparts. To show the overall impact on the emissions of the three-wheeler market in Dar es Salaam, we compare three scenarios: benchmark, moderate, and optimistic. The results from the comparison of benchmark and optimistic are shown in the figure below: we conclude that if by 2030, 70% of the three-wheelers that are sold are electric ones, CO2 emissions of the fleet could drop by 29% from the benchmark scenario.

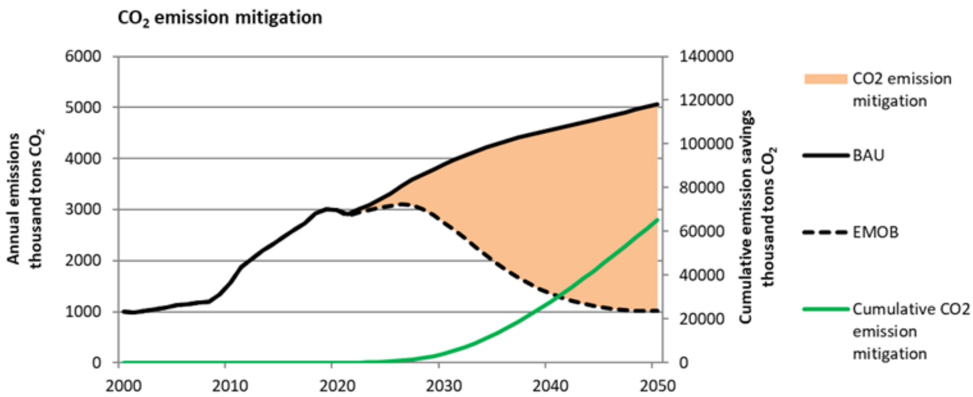


Figure 5. The effect of electric three-wheelers on CO2 emissions in Dar es Salaam

Social indicators were assessed using diverse methodologies, including accessibility analysis, but also expert inputs. The project's impact on the accessibility of public transport (SDG 11.2) was assessed using the widely acknowledged concept of Sustainable Development Goals (SDGs). The results indicated that the project would help to increase the accessibility of public transport for the overall population. However, a slight negative effect on road safety was identified, which mainly stems from the fact that electric three-wheelers are less noisy than their ICE counterparts. Nevertheless, the project is expected to result in a general improvement in the quality of the mobility service. The wider **economic indicators** suggest that the project could have a significant positive impact on the economy, particularly if local manufacturing and maintenance are considered. However, it should be noted that the full economic effects will only be realised once the project is implemented on a larger scale.

Overall, the project showed that the implementation of electric three-wheelers presents a promising solution to tackle sustainability and transport related challenges in a growing mega city like Dar es Salaam.

Pedal-assist electric bicycles

The **environmental impact assessment** shows that the shift from ICE boda bodas to electric bicycles demonstrates significant potential for reducing CO2 emissions. Substituting an ICE motorcycle with an electric bicycle, under the current characteristics of electricity generation, would result in an annual reduction of 2,723 kg of CO2e, equivalent to a substantial 95% decrease in CO2 emissions. These benefits will increase with the launch of the Julius Nyerere Hydropower dam.

3.6. THE QUITO DEMONSTRATION

The Metropolitan District of Quito (DMQ) is the capital and largest city of Ecuador. It has approximately 2.7 million inhabitants (INEC, 2020) and is in the Pichincha province in the north of the country. The SolutionsPlus actions in Quito focussed on the Historic Center (HCQ) that comprises an urban area of 376 hectares, with approximately 40,000 inhabitants. Due to its location in the centre, the HCQ is an obligatory crossing point for all commuters from the southern area of the city that go to the Central Business District (CBD) and is also a mobility hub.

However, Quito, and particularly the HCQ, face various problems regarding freight and passenger transport. Some of the main problems regarding freight transportation in the HCQ area relate to infrastructure that is characterized by narrow streets, high population density as well as restrictions to motorized traffic. The current restrictions do not allow the entry of regular medium and large freight vehicles to pedestrianized areas during daytime, increasing the costs for shop owners. As some streets in the Historic Centre have been converted into pedestrian corridors, this resulted in difficulty in the distribution of goods in the area. Together, these characteristics hinder the economic activities of the HCQ. Regarding personal mobility, the main problems in Quito relate to congestion, dispersed transport services, low perceived quality and comfort of public transport, and a lack of capacity of current services. These problems contribute to the use of private vehicles instead of using public transport. To tackle these problems, the SolutionsPlus actions in Quito comprised two components: piloting of e-cargo bikes and piloting of a mobility-as-a-service (MaaS) application for public transport.

The first component involved piloting seven e-cargo bikes to serve delivery logistics, restaurant logistics and recycling in the HCQ area. Three different locally manufactured e-cargo bike models were used between November 2022 and January 2023. For delivery logistics, the implemented long-john e-cargo bike after tax net present value was 8,021 USD, internal rate of return 98,0% and payback period 0.97 years, based on the data collected during the pilot implementation. For restaurant logistics and recycling, which are not revenue generating activities, cost-effectiveness ratios were calculated. For restaurant logistics, the cost-effectiveness ratio of the implemented e-cargo bike was 1.47 USD per cu.m. and for recycling, 7.47 USD per m3. Regarding CO2 emission reduction stemming from replacing the previous transport solutions with SolutionsPlus vehicles, 247.4 kg per vehicle would be saved annually in logistics deliveries (replacing motorcycles), 173.3 kg per vehicle annually in restaurant logistics (replacing private car), while no reductions would be realized in recycling (replacing manual pushcarts). Overall, the quality and usability of the implemented e-cargo bikes were perceived favourably by the pilot participants, implying that they might be a good fit for the rather challenging circumstances faced in the HCQ area.

The second component involved piloting of a MaaS-application that allowed users to plan multimodal trips, access information regarding timetables, public transport routes, schedules, stations and stops as well as purchase tickets for public transport. The pilot took place during one month between November-December 2022, during which 45 students used the developed application prototype. Several usability issues hindered application usage and realizing its potential in terms of impacts. However, given such issues would be resolved in the future, MaaS-approaches could have a positive impact in terms of public transport accessibility and different reaching destinations, thus contributing to shift away from private cars towards sustainable modes of mobility.

3.7 THE MONTEVIDEO DEMONSTRATION

The Uruguayan capital Montevideo is the country's largest city with a metropolitan population of approximately 1.8 million people and an area of 201 km2. The city is facing economic growth and a population growth in areas outside of the city centre, which leads to growing motorization rates and CO2 emissions from both personal and freight transport. In Montevideo, especially freight transport services suffer from several problems, including lack of space to unload cargo, difficulties in scheduling cargo activities, local commerce concentrating on the central area of the city, as well as long waiting times and delays in cargo operations.

Based on the mapping of local stakeholder needs, the most important aims for the SolutionsPlus project were to assess the financial feasibility of e-vehicles, and to increase the amount of trips conducted with e-vehicles instead of internal combustion engine (ICE) vehicles. Additionally, emission reductions in terms of CO2 and local air pollutants were deemed an important goal among stakeholders. Regarding potential use cases, particularly first and last mile cargo deliveries were deemed relevant.

To tackle these issues, and meet the local user needs, the SolutionsPlus demonstration involved manufacturing and piloting of e-cargo bikes in delivery services. The duration of the pilot was 2 weeks, during which a total of 156 delivery trips were conducted, covering 187 km and a total of 90 package deliveries. Two different models (i.e., long-John e-cargo bike and an e-3-wheeler) were manufactured and tested to accommodate the pilot.

Based on the pilot demonstration, with the income tax rate of 25%, and depreciation rate of 12%, the after-tax NPV is 2,521 USD, after- tax IRR 47.0%, and after-tax payback period is 1.8 years for the long john e-cargo bike model. For the e-3-wheeler, with the income tax rate of 25%, and depreciation rate of 12%, the after-tax NPV is 2,605 USD, after tax IRR 41.6%, and after-tax payback period 1.9 years.

Based on the assumption that the SolutionsPlus vehicles replaced ICE 2-wheelers (0.04 kg CO2/km), the deployment of two e-cargo bikes during the pilot for a total distance of 187 km decreased CO2 emissions by 7.48 kg. The yearly extrapolated CO2 savings per vehicle, considering the distance of 16,992 km is 670 kg.

Several hurdles hindered realizing full potential of the e-cargo bikes in the pilot demonstration. Firstly, pilot participants were unfamiliar with e-cargo bikes and the short duration of the pilot did not allow participants to become familiar with the new types of vehicles. This led to shortcomings in terms of how the vehicles were perceived and how efficiently they were operated. Secondly, the business and operational model that focused on direct deliveries from business to customer did not take full advantage of e-cargo bike benefits, such as their capacity to carry more cargo than conventional ICE motorbikes.

To mitigate the problems faced during the pilot implementation, future efforts should be dedicated to finding and refining the use cases to allow taking advantage of the potential of e-cargo bikes. Additionally, efforts should be made to profoundly familiarize the users with the new types of vehicles to avoid unnecessary troubles in day-to-day operations.

3.8. THE MADRID DEMONSTRATION

This section presents the work performed by the SOLUTIONSplus consortium for the impact assessment task of the Madrid demonstration project. It starts with some background and context of the city of Madrid, describing the location and geography, the climate as well as the population and urbanisation. Then the urban transport system is described including the different operating companies. Further, the sustainability strategy “Madrid360” which frames a favourable environment for electric mobility, setting ambitious goals for electrification is shortly described. An identification of the main problems shows that the road transport sector is one of the main responsible for GHG emissions. Regarding passenger transport, since the early 2000s, Madrid has been testing different types of electric and hybrid buses. Thus, it has made great progress in improving the environmental performance of its fleet.

The SOLUTIONSplus Madrid pilot is led by EMT, Empresa Municipal de Transportes de Madrid, a public company owned by the Madrid City Council that was created in 1947. EMT operates and manages the whole network of urban public buses in the city and is also responsible for additional mobility services such parking, tow trucks, public bike sharing system –BiciMAD-, cable car. The living lab in Madrid focuses on smart charging systems including inverted pantographs for the e-buses in the city. Therefore, the relevant stakeholders and user needs have been identified by means of a user needs assessment (UNA). The UNA was to be performed via two activities: (i) an online survey and (ii) a set of stakeholder and expert interviews. Both are designed to grasp the perspective of local decision makers, operators and relevant stakeholders with respect to e-mobility and therefore investigate the suitability of the e-mobility solutions to be tested in Madrid vis-à-vis their needs and requirements as well as local barriers and opportunities.

The next step was to identify a set of priorities of the stakeholders relevant for the Madrid pilot regarding electrification of urban mobility. Priorities are formally determined through the weights assigned to a list of selected attributes (KPIs) which apply to all project pilots. The attribute weighting activity in Madrid took place in conjunction with the stakeholder interviews organized within the UNA task. For the investigation of the conceptual impact assessment questions and the calculation of related KPIs the needed data has been defined. Further, a baseline scenario considering existing trends in passenger and freight transport was defined in order to define and calculate the baseline KPI values. Within the baseline KPI values trends as the increasing population, energy supply data as well as the bus fleet composition per drivetrain technology (Diesel, CNG, hybrid and electric) have been considered.

In the ex-ante assessment for the demonstration action in Madrid the focus related to the charging technologies of e-buses and the expected effects have been described. Therefore, detailed specification of the inverted pantograph chargers from ABB have been given and innovative charging concepts as smart charging and vehicle-to-grid have been explained. Afterwards, the impact of the inverted pantograph charging in combination with smart charging have been described including potential saving for energy costs by means of peak shaving.

In the ex-post assessment measurement data from EMT Madrid regarding energy consumption and power measurements recorded in the Bus depot Carabanchel in Madrid have been analysed. In there, the max. power has been assessed depending on the month, day of the week as well as the fluctuations during the day. These data have been compared with potential costs savings and grid impact from literature. Also, an analysis of electricity prices in the EU in 2022 has been conducted and potential cost savings and grid impact for different charging strategies (e.g. peak shaving, day-ahead trading, provision of grid services as FCR) have been estimated. It can be concluded that the peak-shaving algorithm reduces costs by 22.8% to 31.9 % compared to conventional charging, but more advanced charging strategies like DAM (forecasting electricity prices) trading and V2G (vehicle-to-grid) result in only marginal further savings. Based on that the impact of smart charging strategies and the related hardware have been analysed by means of technical KPIs (e.g. max. Power) as well as financial KPIs (e.g. payback period, net present values). It was shown that the payback period for the smart charging hardware and software was very short (1.15 years) and a net present value of about 281,000€ resulted in a calculation for 15 years.

Finally, the impact of a second-life battery storage for self-consumption optimization has been investigated. Therefore, photovoltaic systems with 300 kWp and 750 kWp have been considered in combination with the battery storage. The amount of excess energy has been calculated for both variants and the impact of higher self-consumption and less feed-in energy to the grid. It can be concluded that the energy storage only makes sense for a very high amount of energy surpluses, which is currently not the case with the assumed 300 and 750 kWp systems.

3.9. THE HAMBURG DEMONSTRATION

This section presents the work performed by the SOLUTIONSplus consortium for the impact assessment task of the Hamburg demonstration project.

Demonstration activity and context

In recent years, new mobility solutions have been introduced in cities around the world. In particular, electrification and digitalisation have facilitated the emergence of shared mobility services and shared vehicle schemes.

However, the proliferation of shared e-kick scooters has fuelled the debate on the drawbacks of micro-vehicles. The current operation areas of shared mobility solutions are mainly limited to inner cities, where a high level of public transport is already achieved. Dockless shared micro-vehicles have been criticised for obstructing pedestrian infrastructure and blocking access to buildings and public transport stations, especially for the visually and mobility impaired. Privately operated sharing systems are often poorly regulated, including the number of vehicles, the area of operation, or the parking of shared scooters and bicycles. Furthermore, the positive contribution of electric scooters to decarbonisation is questionable, as the production of the vehicles and the operation of the share scheme are carbon intensive. Finally, shared micro-vehicles are accused of mainly replacing low-carbon modes of transport rather than car trips, and thus actually increasing greenhouse gas emissions. This is mainly due to their limited operational range, with typical scooter trips covering distances of up to 2.5 km.

On the other hand, integrating micro-mobility with public transport has the potential to fill mobility gaps in the collective transport system, which remains the backbone of sustainable urban mobility. As a first and last mile link in intermodal journeys, shared e-scooters can facilitate combined trips and replace car travel, despite their limited range. For example, Hamburg's ITS strategy mentions the *"linking of public mobility, sharing and on-demand services, [...] and the further expansion of mobility hubs as a means to reduce transport-related CO2 emissions"* (Freie und Hansestadt Hamburg 2021), and the European Mobility Framework states that *"new mobility services are part of a multimodal, integrated approach to sustainable urban mobility. They can reinforce public transport and substitute car use".*

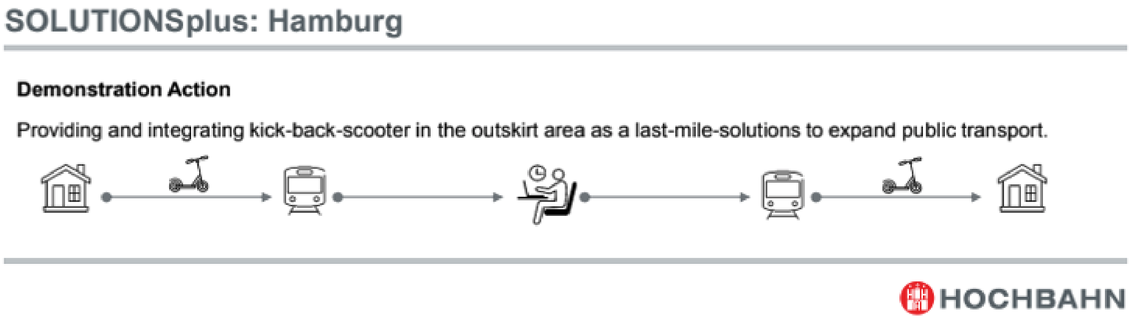


Figure 6. Outline of the Hamburg demonstration activity

In that sense, the Hamburg demonstration activity assessed the potential of free-floating shared e-scooters to complement public transport systems in suburban areas. The public transport operator, HAMBURGER HOCHBAHN, subcontracted a shared e-scooter operator and provided seed funding to introduce shared scooters in the demonstration areas in two Hamburg suburbs. Dedicated parking spaces were provided at four public transport stations in the demonstration areas. During the demonstration period, shared scooter schemes have been integrated into the public transport app.

Stakeholders and KPIs

The selection of relevant key performance indicators (KPIs) for the assessment of the demonstration activity followed a structured approach, which was deployed in all SOLUTIONSplus demonstration activities. The quantitative weighting exercise was complemented with qualitative stakeholder interviews.

Main stakeholders, both from public authorities and the private sector rated the relevance of pre-defined KPIs for assessing the demonstration activity. Impacts on greenhouse gas emissions and on air and noise pollution were considered the by far most critical effects, followed by the contribution to urban strategies and targets. Impacts on society were considered as less relevant – with the exemption of the impact on travel time. The latter can be understood as an effect on the competitiveness compared to private car use. Financial aspects were not rated high, potentially because the shared vehicle scheme is operated by a private company and not continuously subsidised from public budgets.

Stakeholders did not consider the demonstration to have a macroeconomic impact on the wider economy.

Data collection

As part of the sub-contracting between the SOLUTIONSplus partners and the service provider, an agreement was made to share relevant vehicle data. The vehicle data collected included the number of vehicles used during the demonstration period, the origins and destinations of trips, the total number of trips, trip distances and the proportion of journeys starting and/or ending at public transport stations. In addition, HAMBURGER HOCHBAHN conducted a survey of users of the shared e-kick scooters to obtain information on, among other things, the proportion of intermodal trips, the modes of transport substituted and the extent to which trips were induced, i.e. trips that would not have been made in the absence of the sharing scheme. All collected data was anonymised before use in the project context.

Other data had to be estimated or derived from literature reviews. In particular, the LCA-based greenhouse gas emissions per scooter-km varied substantially, from less than 40 g CO2e per vehicle-km (vkm) to more than 130. The main reasons behind the vast range of estimates are diverging assumptions about the greenhouse gas intensity of vehicle production (e.g. depending on the use of secondary vs. raw materials), the expected lifetime of the vehicles (with very low assumptions for the first-generation e-scooters), and emissions related to service operations (diesel vans and collection of entire e-scooters for recharging vs. e-cargo bikes and vehicles with removable batteries). The vehicles deployed during the demonstration activity were recent models and expected to have a longer lifetime compared to the first-generation scooters. They have removable batteries and service was performed by electric vans. In consequence, the LCA-based emissions per vkm would tend to be at the lower end of estimates. In order to avoid overestimating the GHG reductions, however, a conservative approach has been taken and a value of 67 g CO2e per vkm has been used. This value is the median of the studies reviewed and is at the upper end of more recent assessments. Moreover, we assumed that all deployed vehicles were additional and newly procured, and not redeployed from other areas of operation. Moreover, we assumed that no changes in private vehicle stocks or public transport vehicle-km result from the demonstration activity.

Results of the demonstration activity and upscaling

The results of the assessment have shown that shared e-scooters in the outskirts have the potential to contribute to mitigating transport-related carbon emissions. A mitigating effect on greenhouse gas emissions, however, is contingent on factors such as the number of additional e-scooters, assumptions about the indirect greenhouse gas emissions from scooters and operations, and the share of car trips replaced. SOLUTIONSplus data indicated that during the demonstration stage, approximately one third of all scooter trips were part of intermodal travel chains and that 26% of scooter trips replaced a car trip.

Based on our assumptions, the assessment found that the introduction of e-scooters had a mitigating effect on greenhouse gas emissions when only those scooter trips were considered that are part of intermodal travel chains (as approximation we assumed that trips that start or end at a public transport station are part of intermodal travel chains). When all e-scooter trips in the demonstration area were considered, however, the demonstration activity was found to cause additional emissions. This negative impact was mostly due to the number of deployed additional newly produced scooters (as the scooters remained in use after the demonstration period, a discounting factor could be used to cover the entire vehicle lifetime).

As assumptions about vehicle-related emissions are highly uncertain, we used scenarios to understand (a) how high GHG emissions per vkm could be and (b) which share of car trip replacements would be required to achieve a net-zero effect compared to the current situation.

Table 12. Compiled results of impacts on greenhouse gas emissions

	ONLY INTER-MODAL TRIPS IN DEMO AREA	ALL E-SCOOT-ER TRIPS IN DEMO AREA	BREAK-EVEN CO2E PER SCOOTER-KM	BREAK-EVEN % OF CAR TRIPS RE-PLACED	
Additional emissions					
Scooter-km to/from public transport stations	34.808,07	175.380,65	175.380,65	75.380,65	vkm
Emission factor scooter-vkm (LCA)	67	67	**47,03**	67	gCO2e / vkm
Additional emissions from e-scooter trips to/ from public transport (vkm*emission factor)	2.332.140	11.750.503	8.247.482	12.276.645	gCO2e
Avoided emissions					
Number of scooter trips to public transport stations	35.403	35.403	35.403	35.403	number
Share of e-scooter trips that replace car trips	26	26	26	**38.7**	%
Number of replaced car trips	9.205	9.205	9204,78	13.702	trips
Average distance of car trip	5,60	5,60	5,60	5,60	vkm/ trip
Shifted vkm fom car to intermodal	51.547	51.547	51.547	76729	vkm
Emission factor car-km	160	160	160	160	gCO-2eq / vkm
Avoided emissions	8.247.482	8.247.482	8.247.482	12.276.645	gCO-2eq / vkm
Net avoided emissions	**5.92**	**- 3.50**	**0**	**0**	**tCO-2eq**

The scenarios found that, all other factors being kept constant, a positive mitigation impact would be achieved if:

a. LCA-based emissions per e-scooter-km would be below 47 gCO2e, which is within the lower range of recent LCA studies; or if
b. 38.7% of all scooter trips replaced car trips. This would require an increase by 12.7 percentage points compared to the survey results.

We assume that the demonstration activity has a mitigating impact on local air pollution and noise pollution, by reducing the use of cars with internal combustion engines. Quantifying the effect was not possible, however, since the routes of the replace car trips, along which the impact would occur, are not known.

In terms of accessibility, the solution complements the existing transport system in areas where public transport is less dense. However, it cannot be considered as a universal solution to improve the accessibility of public transport, as shared e-kick scooters exclude children, the elderly, and people with disabilities; the vehicles are also not suitable for travel related to activities such as childcare or grocery shopping. Rather, the solution targets those groups that tend to use private cars for their purposes, mostly commuting and leisure, and increases the attractiveness of intermodal public transport services. Other new mobility services, such as ride-hailing, ride sharing and car-sharing services, should be explored to address the shortcomings in terms of accessibility and to cover a wider range of use cases and user groups.

In the scaled-up scenario we assumed that shared vehicle services are provided in the entire city area, using a similar ratio of vehicles per inhabitant as in the demonstration area. Assumed that the required ca. 9,000 e-scooters would be newly built vehicles, greenhouse gas emissions would rise by ca. 9,500 tCO2e. However, if the currently operative 20,000 e-scooters would be re-distributed across the city area, an emission reduction of 15,400 tCO2e could be achieved. Compared to a total of 3.435.000 tCO2e, this would amount to ca. 0.4% of transport-related greenhouse gas emissions.

Conclusions and recommendations

The demonstration activity has indicated that shared micro-vehicles can support the decarbonisation of mobility, given that the number of new vehicles is limited and LCA-based emissions per scooter-km are at the lower end of the range of estimations. Tendering for concessions with attached provisions on vehicles and operations can encourage e-vehicle providers to become more sustainable. Low-carbon operations and extending vehicle lifetimes are crucial for achieving a positive climate impact of shared micro-vehicles. Achieving higher replacement rates for private car trips require push measures, including the removal of parking spaces in inner cities, the extension of parking management, or pedestrianisation of urban space.

3.10. THE NANJING DEMONSTRATION

Situated in the lower reaches of the Yangtze River, Nanjing covers an area of 6,598 square kilometres and is a pivotal part of the vast Yangtze River Delta economic zone. This region is crucial, as the Yangtze River basin, spanning approximately 700,000 square miles, supports almost one-third of China's population of 1.3 billion and accounts for more than 40% of the country's GDP.

Nanjing participated in the SOLUTIONSplus project as an associated partner. The city received capacity-building support but no funding for activities in China. The Nanjing demo was based on installing the Low Carbon Mobility Management (LCMM) app on the smart phones of private car and public bus drivers and using the app's feedback on each driver's driving behaviour to motivate eco-driving.

3.10.1. The LCMM tool

The LCMM technology, developed in 2011–14 by Deutsche Telekom AG, combines mobile communication with smart phones, GPS profiling and cloud-based computing. Based on real-time GPS monitoring of vehicles and using vehicle technical parameters linked to the user profile, LCMM analyses a driver's behaviour and provides timely feedback on fuel efficiency, journey summary, and driving behaviour categorization on the driver's smart phones. The LCMM platform functions include detailed analysis and display of all driving data, data export, and reporting. Previous applications of LCMM generated between 8% and 15% fuel savings. Eco-routing and eco-driving are important approaches for saving transport fuel, reducing GHG emissions and local air pollution, and avoiding traffic congestion and accidents. ISO recently issued a two-part standard related to intelligent transport systems based on several similar digital tools and solutions (ISO/DIS 23795).

3.10.2. The Nanjing demo activities

The Nanjing demo under the SOLUTIONSplus project consists of two parts: 1) establishing a regional training centre and offering training on sustainable and smart transport, including e-mobility, and 2) demonstration of LCMM use among private car drivers.

The training program started in September 2021, and as of August 2022, the training centre had organized seven online and in-person training events, with around 100 in-person and over 70,000 online participants.

With regard to the LCMM app, the demo developed in three stages: Stage 1 involved eight private cars (six in Nanjing and two in Beijing) and a bus (in Nanjing). Although SOLUTIONSplus focuses on electric vehicles, all private cars of Stage 1 were ICE ones. This is because even though e-buses are common in Nanjing, the ownership of electric cars is still low. As Stage 1 results indicated challenges due to the demo's small sample size and limitations in adapting the LCMM App for China, an extension of the demo through Stages 2 and 3 on electric taxis in Nanjing was decided.

Stage 2 involved only one taxi. The objective was to recalibrate the LCMM parameter settings by recording the e-taxi's actual electricity consumption and comparing it with the electricity consumption data estimated with the LCMM app.

Stage 3 consisted of a baseline demonstration without LCMM, and a comparative demonstration with active LCMM. In the latter demonstration, which involved four electric passenger cars with 12,000 km of data, the drivers could see real-time assessment results on their driving performance compared to the optimal indicators, illustrated as green (good), yellow (average) and red (poor) segments of their trip route. The LCMM app stimulates eco-driving behaviour based on the assumption that when the drivers see the real-time assessment of their driving performance, they will be motivated to make corrections and improve their driving performance.

3.10.3 The impact assessment process and results

The project team assessed the data collected for the demo cars, and the result indicated 8.7% improvement in driving performance (fuel consumption reduction). The bus data was not included in the assessment as LCMM app only captured the driving performance data for a few trips. Moreover, in China, bus drivers are forbidden to watch their phone screens while driving, and there is camera surveillance on buses to ensure that bus drivers comply with the driving rules in Nanjing. As a result, bus drivers could not check their mobile phones while driving to access the LMCC feedback on their driving behaviour.

The LCMM project in Nanjing is recognized as a significant National Key Research initiative, receiving accolades and financial support from two Chinese ministries. Furthermore, the inclusion of Nanjing in the SOLUTIONSplus project represents an important collaboration between the EU and China.

3.10.4 Recommendations for future scale-up

In view of the fast growth of vehicle ownership in China, eco-driving and intelligent transport can make significant contributions to fuel and cost saving, reduced GHG and pollution emissions, reduced travel time, improved road safety, and improved social well-being without expensive investments.

The results of the Nanjing demo provide valuable insights for scaling up the LCMM app and similar products. Addressing the privacy concerns of drivers in sharing information is such a direction. An idea is to integrate the LCMM into the popular GPS services in China, as most drivers use GPS services when driving. Another solution is to provide vocal feedback to the drivers instead of visual signals, so they do not need to look at their phones regularly. A third option is to promote the application of LCMM among companies with large fleets, use peer competition among drivers, and provide monthly eco-driving awards.

LCMM is based on accurate and real-time GPS data collection on vehicles. The enormous amount of data collected through LCMM also provides valuable inputs that cities can use to monitor and regulate traffic flows, take preventive measures, and quickly respond to traffic jams or road accidents. The results of LCMM can also be used to track everyone's carbon footprint to drive and encourage environmental and green lifestyles.

4 HORIZONTAL COMPARISONS AND LESSONS LEARNED

This section attempts a horizontal comparison of the ten demonstration projects as presented in Section 3, aiming at identifying lessons learned regarding the scalability and transferability of the demonstrated technologies, as well as the corresponding preconditions. Note that some of the demo activities have been undertaken in just one project city precluding any comparison attempt. These cases, such as the inverted pantograph technology for charging e-buses in Madrid or the LCMM platform for eco-driving in Nanjing, will be excluded from this discussion despite their effectiveness in achieving the intended objectives. The section's comparisons have been grouped into four themes: user needs, light duty passenger EVs, light duty freight EVs, and MaaS applications.

4.1 USER NEEDS

4.1.1 Introduction

Understanding the heterogenous e-mobility user needs across different contexts in the different regions of the world is a crucial task. In particular, there is a pressing need to unfold the perceived importance of EVs to affect mobility patterns, quality of life and the city environments and correlate these perceptions with external factors such as noise, air pollution, and traffic congestion. Moreover, in order to inform policy and practice, and support the transition to EVs, it is important to identify expected challenges in penetrating the respective local markets.

The project's demonstration activities in nine[7] cities of four continents with its different types of innovative and integrated e-mobility solutions therefore offer a unique opportunity to gain and compare first-hand experiences. Accordingly, a user needs analysis was undertaken by the project consortium in each of the living labs to identify the stakeholders involved and verify the suitability of the planned interventions. Specifically, this analysis aims to: (i) summarize the main user-needs related findings of the living labs, and (ii) investigate the effect of the external environment on these needs through a horizontal analysis cutting across cities.

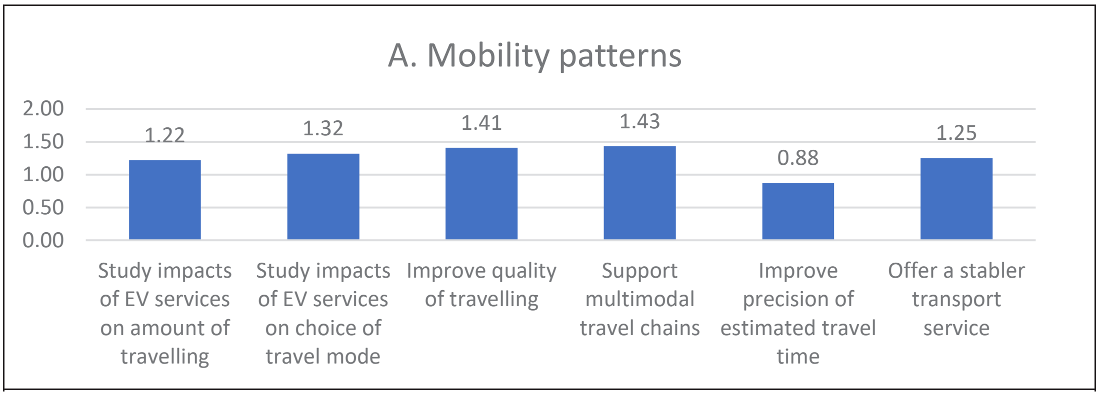
The analysis was conducted through an online self-completion survey, supplemented by expert interviews. Relevant stakeholders included representatives from institutions representing government authorities (national, regional, local), transportation companies and operators (public, and private), e-vehicle manufacturing and servicing companies, entities that work in the sphere of electricity and charging, academia and NGOs. Data collection took place between November 2020 and January 2021. There were 90 valid responses from nine cities in total.

Overall, the findings contribute to selecting strategic orientations for the promotion of e-mobility in urban transportation that are aligned with the preferences and priorities of the local stakeholders.

4.1.2. The analysis

Perceived importance of electric vehicles

Among others, the SOLUTIONSplus survey on user needs analysis included three questions investigating stakeholder perceptions in relation to: (i) mobility patterns, (ii) city environment, and (iii) quality of life. A list of project objectives was suggested for each one of these areas, and the stakeholders were asked to assess the importance of these objectives on a 5-point Likert scale ranging from -2 ("not important at all") to +2 ("very important"). The assessed objectives and the corresponding scores are shown in Figure 7. The main findings are summarized below together with interesting arguments expressed during the supporting interviews.



7 The Nanjing city has been excluded from this analysis, as the relevant information was not available at the time of drafting this section.

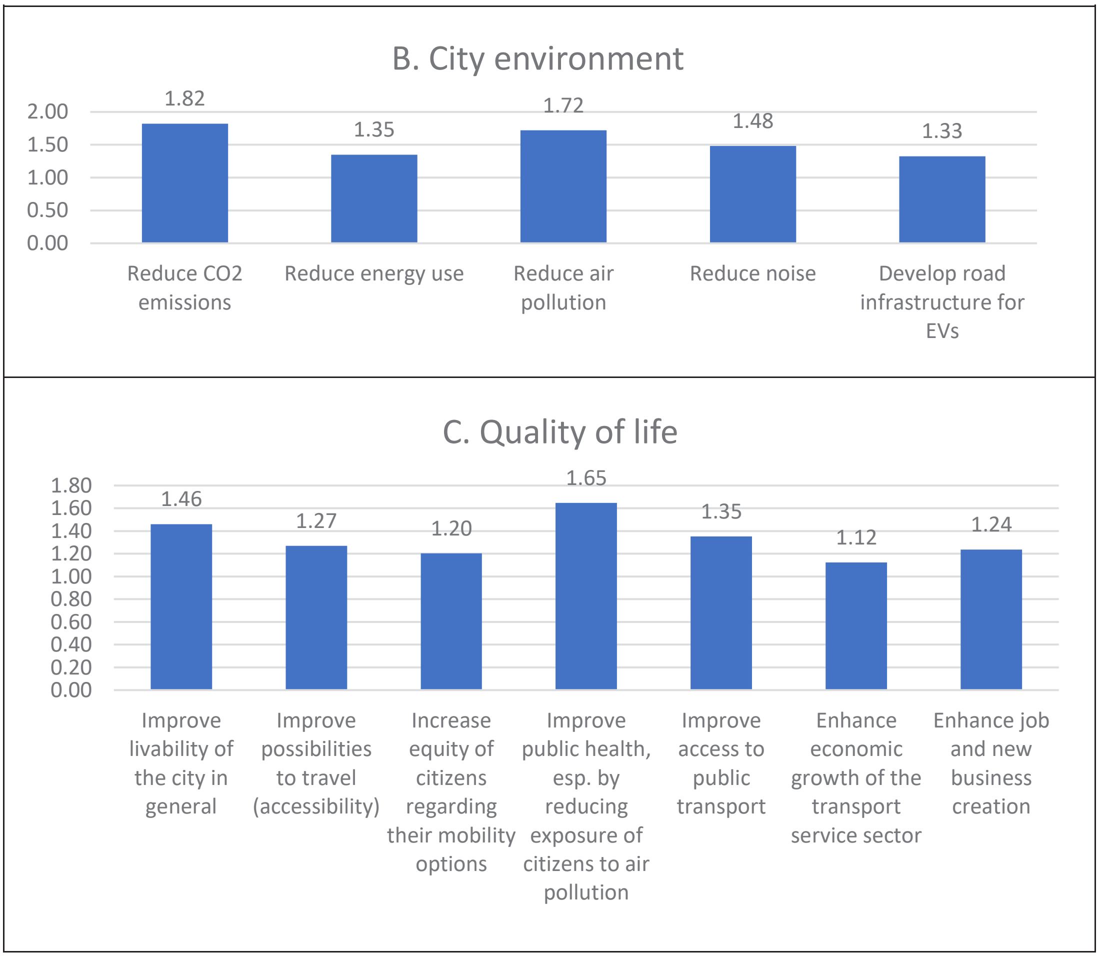


Figure 7. Stakeholder perceptions of the importance of project objectives

All six objectives in the area of mobility patterns were scored positively, indicating that overall, they were perceived as important. The highest score (1.43) was given to the “support of multimodal travel chains,” as the scheduled demonstrations in several project cities concern the first/last mile transport. With a score of 1.41, the importance of e-mobility in “improving the quality of travelling” was also highly rated. The role of e-mobility in “improving precision of the estimated travel time” was valued as the least important aspect by far, which is not surprising given the heavy traffic conditions in many of the project cities.

When it comes to the expert interviews, it was widely seen that having a broader set of innovative electrified modes available would increase multimodal and intermodal trips, thereby (hopefully) contributing to a reduction of private car use. Investigating the feasibility of e-mobility transformations, together with incentives that could promote e-mobility were also suggested as project aims.

All project aims suggested in the field of environment were scored between +1 (“important”) and +2 (“very important”). The reduction of CO2 emissions attracted higher attention (1.82) than that of air pollution (1.72) despite the global nature of the former. This is no surprising given the increased societal sensitivity of the climate change challenge. Neither the appearance of noise reduction in the third place (1.48) was a surprise. The promotion of environmental education and the need to enhance public awareness of e-mobility solutions were identified as additional aims during the expert interviews.

With a score of 1.65, the role of e-mobility in improving public health was deemed the most important one, followed by improvements in the general liveability of the city (1.46) and the access to public transport (1.35). Although still more than "important" (1.12), potential economic growth generated by e-mobility in the transport service sector was the least favoured option. In terms of city liveability, the experts expressed concerns relating to land use planning with emphasis placed on the need to segregate space for public and active transport to the detriment of motorized traffic.

Challenges in market penetration

The survey further revealed insights as to the barriers towards implementing e-mobility, deemed most challenging by the respondents. The cumulative percentage of respondents across all project cities that mentioned each of the listed challenges appears in Figure 8. The vast majority of them (66% and 65%, respectively) sees investments in infrastructure and the lack of financial resources as the most significant challenges. More than half of the respondents (52%) also agree that the lack of enabling policies is an important obstacle in the transition to e-mobility. Organizational issues, lack of maintenance services, and low acceptance of EVs among stakeholders/users follow in significance exhibiting frequencies above 30%.

From a regional perspective, infrastructure and financial resources remain in the top-3 challenge lists for all continents. Enabling policies, however, enter the top-3 only in Asia and Latin America. The third place in Africa is occupied by maintenance services, while in Europe it is shared among organizational issues, lack of service operators and low EV acceptance among passengers, each one with 33%.

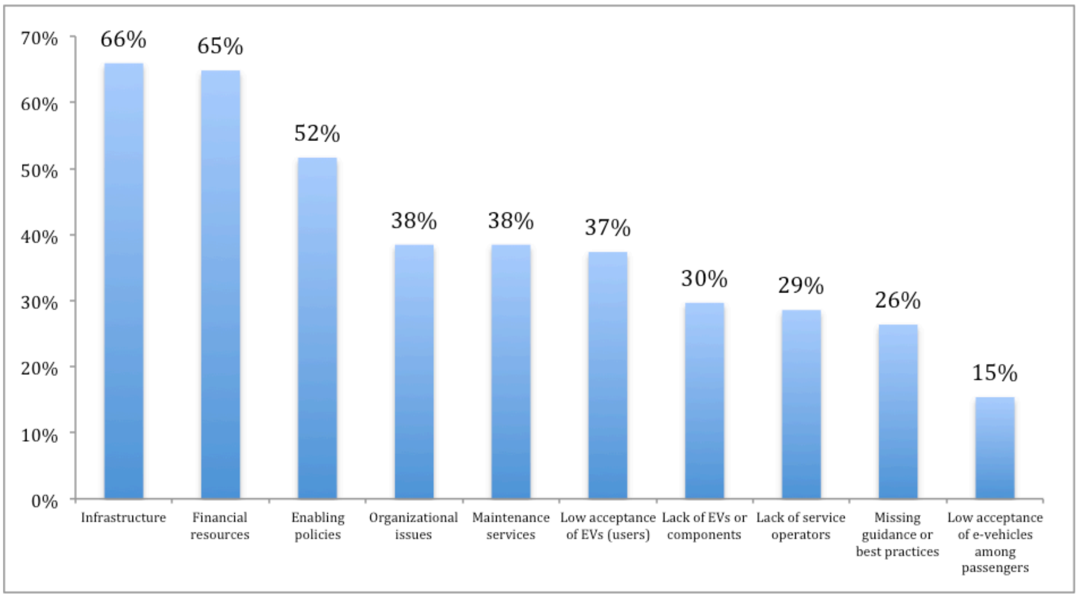


Figure 8. Main challenges identified across all SOLUTIONSplus cities

Issues of interest that surfaced through interviews include regulatory and governance aspects that hinder e-mobility proliferation (in 3 out of 9 cities), the lack of technical standards (4/9), and the lack of clear/sufficient homologation and registration regulations for EVs (4/9). The capacity of the electricity grid to meet the electrification challenge, lack of technical skills, concerns with regard to urban planning and space requirements for the implementation of e-mobility solutions, as well as diverging objectives of different stakeholder groups were also referred to as problems to be addressed.

The role of selected external factors

When comparing the results of the online survey across the nine demonstration cities, some notable differences can be observed suggesting that the role of e-mobility is perceived differently depending on the context of the respective city. Although some variation is likely caused by the small sample size, we expect that external factors affect the different perceptions.

Figure 9 disaggregates the “mobility patterns” and “quality of life” results of Figure 7 by city. The descriptive statistics thereby deliver two insights that are particularly striking: First, for many indicators – mainly travel and mobility related – the City of Pasig received the highest scores. Interestingly, for indicator 6.5 (“To improve precision of estimated travel time”) it received a score of 1.69, while all other cities show values of 1.00 or less. This indicator has the lowest average of all indicators, but the highest standard deviation in the sample (AVE=0.88, SD=1.08).

Second, the overall highest score has been found for the city of Kathmandu, with a value of 1.94 for indicator 10.4 (“To improve public health in general, esp. by reducing exposure of citizens to air pollution”). This indicator also received the highest average in the sample (1.65).

We interpret the results in the following way: Indeed, Pasig City is part of one of the most congested regions in the world – Metro Manila, the national capital region of the Philippines – that is notorious for its traffic gridlocks, while Kathmandu, on the other hand, is one of most polluted cities in the world. It appears that where air pollution or traffic congestion is high, e-mobility is seen as a solution to mitigate these types of externalities. In contrast, where air pollution and/or traffic congestion are not perceived as a major issue (e.g., Hamburg), the expected benefits of e-mobility solutions are likely influenced by other challenges the cities face. In the context of Hamburg, this appears to rather be the case for social issues such as providing more equitable and accessible transport services (indicated by the high scores for indicators 10.5, 10.3 and 10.2).

			All Cities (N=90) AVE	SD	Hamburg (N=8)	Hanoi (N=9)	Kathmandu (N=16)	Montevideo (N=14)	Pasig (N=13)	Quito (N=19)
Mobility patterns	6.1	To study impacts of e-vehicle services on the amount of travelling (no. of trips and/or km	1.22	0.82	1.00	1.11	1.50	1.29	1.31	1.47
	6.2	To study impacts of e-vehicle services on choice of travel mode	1.32	0.80	1.13	1.22	1.50	1.21	1.31	1.47
	6.3	To improve quality of travelling	1.41	0.74	1.13	1.00	1.63	1.50	1.77	1.29
	6.4	To support multimodal travel chains	1.43	0.77	1.63	1.33	1.25	1.07	1.77	1.59
	6.5	To improve precision of estimated travel time	0.88	1.08	0.63	0.89	0.81	0.93	1.69	1.00
	6.6	To offer a more stable transport service	1.25	0.87	0.63	1.11	1.38	1.29	1.85	1.25
Quality of life	10.1	To improve livability of the city in general	1.46	0.78	1.13	1.44	1.56	1.21	1.85	1.33
	10.2	To improve possibilities to travel (accessibility)	1.27	0.85	1.25	1.33	1.38	0.93	1.62	1.33
	10.3	To increase equity of citizens regarding their mobility options	1.20	0.91	1.50	0.89	1.13	1.21	1.77	1.22
	10.4	To improve public health in general, esp. by reducing exposure of citizens to air pollution	1.65	0.66	0.75	1.44	1.94	1.50	1.92	1.72
	10.5	To improve access to public transport	1.35	0.94	1.63	1.22	1.44	1.00	1.77	1.29
	10.6	To enhance economic growth of transport service sector	1.24	0.84	0.00	0.78	1.63	0.57	1.62	1.28
	10.7	To enhance job creation and new established businesses	1.24	0.78	0.25	1.00	1.50	1.07	1.54	1.56

Figure 9. Results of the expert survey for Indicators 6 (Usage and mobility patterns) and 10 (Quality of life in the city) [Note: Only cities with at least 8 valid responses are included in this overview (Dar Es Salaam, Kigali, and Madrid are therefore missing)]

To further investigate the role of external factors, we compare indicators 6.5 and 10.4 with numeric indices of external factors that describe the state of i) the mobility and ii) pollution in the cities. We use the traffic congestion and pollution index from Numbeo.com, and plot them against the experts' answers.

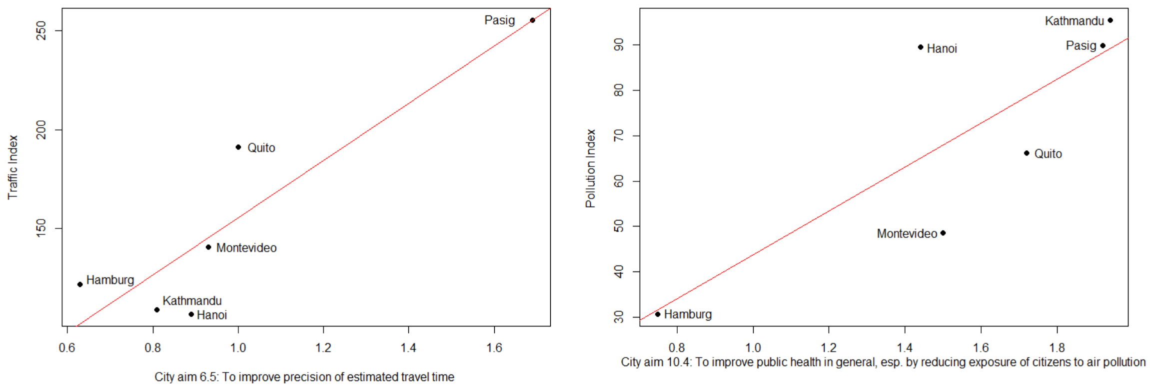


Figure 10(a+b). Traffic index vs. city aim 6.5 (left) and pollution index vs. city aim 10.4 (right). [Note: The value of Pasig City for both indices relates to Metro Manila, of which Pasig City is part of]. Source: Numbeo Traffic Index by City 2022 and Pollution Index by City 2022 (values as of May 2022).

The results of the traffic index against city aim 6.5 is shown in Figure 10a. It shows a positive correlation, where a high value in the traffic index indicates more congestion, and which is likely to result in higher scores of responses to city aim 6.5. In the city of Pasig, accordingly, the need to improve the precision of the estimated travel time is perceived very high, especially in relation to the other cities, where traffic jams seem to be less of a problem. Indeed, travellers in Pasig are often stuck in traffic, and the demand for more reliable services and multimodal travel information is therefore very high (Hasselwander et al., 2022). The planned demo component of an e-vehicle/services sharing app (refer to Section 4.4) therefore appears to be a suitable measure to exactly address these issues.

City aim 10.4 grasped the question whether the cities aim to improve the health of their citizens, in particular by lowering their emissions. The results of the plot of answers to 10.4 against the pollution index is shown in Figure 10b. Again, a positive relationship can be examined. This indicates that in cities where air pollution is high, especially Kathmandu and Pasig stand out, the associated aims of the cities with the project are higher, while – again in Hamburg – the low pollution index goes along with a least important aim to reduce emissions. We find that also the selection of demo components aligns with this observation. The retrofit of buses to e-buses and redesign of e-3-wheelers in Kathmandu as well as the development of e-quadricycles in Pasig clearly aim at reducing local vehicle emissions. In contrast, while the Hamburg component of integrating e-scooters with public transport has likely no positive impact on reducing emission (Reck et al., 2022), it rather aims at improving access to public transport means.

4.1.3. Concluding remarks on user needs analysis

Overall, our analysis and horizontal comparisons show that external indicators indeed have an impact on the targeted city aims for e-mobility, especially for extreme values (recall the high values for Pasig/Kathmandu versus the low values for Hamburg in the traffic and pollution index). This is an important finding for public policy and practice. Accordingly, a successful transition towards e-mobility requires the identification of both pressing challenges that need to be addressed as well as suitable e-mobility solutions that can provide a remedy. Following, the expected benefits of these e-mobility solutions to address relevant problems in local context need to be communicated effectively to create awareness and increase the overall acceptance of e-mobility.

Although the correlation between the external factors and answers that we analysed can also be explained logically, they require a validation by a larger, representative sample. Furthermore, it is recommended to examine and link the other answers of the expert survey to external factors to possibly support our preliminary findings, and whether they also hold in a more comprehensive data analysis.

4.2. COMPARATIVE ANALYSIS OF CITY-SPECIFIC PASSENGER EVS

In recent years, electric mobility solutions have been promoted to mitigate urban transport's negative externalities. The SOLUTIONSplus project, has implemented demonstration activities to enhance public transportation connectivity for passengers in Africa and Asia. The prototypes have been designed and developed locally in certain instances, manufactured by local enterprises, aiming to substitute fossil fuel-powered two-wheeler, three-wheelers, vans and buses manufactured by local enterprises, aiming to substitute fossil fuel-powered two-wheelers, three-wheelers, vans and buses. The prototypes are designed considering the specific circumstances and objectives of the local context. The following demonstrations have taken place for passenger transport in the project:

- **e-three wheelers** (Dar es Salam, Tanzania) will replace Bajaj ICE models. The pilot focusses on Bajaj's that currently provide feeder services to the Bus Rapid Transit (BRT) system and 25 e-three wheelers were part of the demo.
- **Safa Tempo** (Kathmandu, Nepal). A 20 year old Safa Tempo (3 wheeler) has been remodelled to extend the life of older vehicle.
- **e-three wheelers** (Kathmandu, Nepal). The passenger version of a mini Safa Tempo modular e3W design, easily customised to a passenger, cargo, or waste collection operation.
- **e-moto taxis** (Kigali, Rwanda) will replace ICE motorcycle taxis on the same routes. 24 e-moto taxis were given to women e-moto taxi drivers.
- **e-mopeds** (Hanoi, Vietnam) for providing last mile connectivity between a BRT stop and a shopping mall. A total of 50 Vinfast Ludo e-mopeds were employed by the demo to substitute trips provided by a shuttle bus that operates on diesel.
- **e-shuttle van** (Kathmandu, Nepal) targets the historic areas and heritage routes of Kathmandu. One locally developed protype e-shuttle van will be demonstrated.
- **Bus conversion** (Kathmandu, Nepal) involves converting a diesel bus into e-bus by changing the drive.
- **eBus** (Kigali, Rawanda) involves leasing of 4 ebuses to bus operators in Kigali

4.2.1. Comparison of stakeholder priorities

The KPI weights in the four demo cities appear in Table 13. They resulted from a 2-round Delphi method application involving 10–20 knowledgeable individuals in each city, reflecting the corresponding stakeholder priorities.

Table 13. KPI weights for the demo cities (stakeholders' input)

Level-1	Level-2	Kigali	Dar	Kath.	Hanoi	*Avg.*
Project finances	Financial viability	8.70	8.75	12.25	7.30	*9.25*
	Availability of finance	9.00	7.25	11.19	6.48	*8.48*
	Project finances, total	*17.70*	*16.00*	*23.44*	*13.78*	*17.73*
Institutional framework	Coherence with plans/goals	5.48	5.32	5.86	5.98	*5.66*
	Alignment with legislation	3.91	4.48	5.40	4.61	*4.60*
	Ease of implementation	6.01	4.50	6.39	4.79	*5.42*
	Institutional framework, total	*15.40*	*14.30*	*17.65*	*15.38*	*15.68*
Climate	Effect on GHG emissions	18.40	16.20	13.19	11.35	*14.79*
Environment	Effect on air pollutants	7.56	4.97	6.37	7.08	*6.50*
	Effect on noise	5.69	4.73	4.26	4.02	*4.67*
	Effect on resource use	5.25	7.20	4.84	5.10	*5.60*
	Environment, total	*18.50*	*16.90*	*15.46*	*16.20*	*16.77*
Society	Effect on accessibility	1.92	2.86	2.04	4.47	*2.82*
	Effect on affordability	2.16	2.01	2.16	3.11	*2.36*
	Effect on travel time	2.04	2.57	1.36	4.73	*2.68*
	Effect on road safety	1.87	2.20	1.60	4.11	*2.45*
	Effect on charging safety	1.50	1.85	1.79	3.06	*2.05*
	Effect on security	1.56	2.01	1.23	3.07	*1.97*
	Effect on well-being	1.94	2.32	1.68	2.71	*2.16*
	Effect on service quality	2.21	2.48	1.94	6.50	*3.28*
	Society, total	*15.20*	*18.30*	*13.81*	*31.76*	*19.77*
Wider economy	Effect on budget	5.02	5.68	6.09	4.56	*5.34*
	Effect on external trade	5.17	5.83	5.64	3.03	*4.92*
	Effect on employment	4.61	6.79	4.71	3.94	*5.01*
	Wider economy, total	*14.80*	*18.30*	*16.44*	*11.53*	*15.27*
	Grand total	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*

On average, the weights of the six Level-1 indicators appear balanced across the demo cities, ranging from 14.79 (climate) to 19.77 (society) per cent. Environment and climate stand out as the top priorities for Kigali, while societal and wider economic concerns attract the least weight. In Dar es Salaam, on the contrary, society and the wider economy share the top position, followed by environment and climate. Asian cities exhibit higher dispersion. The project's financial performance attracts the highest stakeholder interest in Kathmandu, followed by the applicable institutional framework. Society is the clear winner in Hanoi, followed by the environment far behind. Climate change appears to be the lowest priority in both Asian cities. Although no proper randomisation of the stakeholder sample was attempted, the participation of individuals from all stakeholder groups makes the results indicative of the city perceptions.

All of the prototypes are made and, in some cases designed by local companies and are meant to replace two and three-wheelers that run on fossil fuels. They are made with local conditions and goals in mind.

4.2.2. Financial analysis

The financial performance of the project vehicles is assessed either through the Net Present Value (NPV), Internal Rate of Return (IRR), and payback period for revenue-earning operations or the Cost Effectiveness Ratio (CER) otherwise. In the context of this report, it was decided to restrict the analysis to IRR, as this is the most suitable indicator for comparison purposes among projects of similar scale. Furthermore, and in order to exclude tax-related effects, the discussion is based on before-tax returns. The calculations assume that investment associated with the acquisition of the demo vehicle is exclusively through own funds and its operation according to an operational profile typical for the existing fossil fuel vehicle type examined in the corresponding demo city.

Among the three 3W demos, the ‘bajaj’ in Dar es Salaam exhibits an IRR of 22.5%. Being a three-seater, it is the smallest of the project 3Ws, also reflected in its purchase price of $ 6,344 on 31 December 2022. Equipped with a li-ion battery of 7.0 kWh, it can execute 10 round trips daily (over a total distance of 130 km) if fully charged overnight and with additional partial recharging during the day. The newly designed 3W in Kathmandu is larger than Dar’s bajaj, as it has a capacity of 6 passengers. With a purchase price of € 8,110 (equivalent to NPR 1,150,000 on 31 December 2022), the vehicle exhibits an IRR of 30.6%. On a similar deployment of 10 round trips and total distance of 100 km/day, its 10 kWh LiFePo4 battery needs to be charged only once overnight, offering sufficient flexibility during daytime.

The remodelled Safa Tempo in Kathmandu is the largest of the project 3Ws. The project vehicle is a remodelled old 3W, where its lead-acid battery is replaced with a li-ion 23 kWh set, while the cabin is refurbished to seat 11 passengers more comfortably. At a price of € 13,760 (approximately NPR 1,950,000 as of 31 December 2022), an investor can purchase one of these vehicles together with a license valid until 2029. Its battery, with an expected life of about 6 years, is sufficient to run 117 km/day (9 trips of 13 km each) with overnight charging only. Under these conditions, an investor can expect a healthy IRR of 57.8%. Seen from a Safa Tempo operator’s viewpoint, however, the picture is different. Until the expiration of its license, an existing Safa Tempo is expected to make a pre-tax profit of NPR 1,280,000. This is earnings foregone for the operator who decides to remodel their vehicle. After accounting for this additional cost, the IRR of a remodelled Safa Tempo drops to 34.0 %, which is still quite attractive.

With a unit price of €1,240 (1,284 USD in Dec 2022), excluding the battery, the Kigali e-moto taxi offers an IRR of 42% for the e-moto drivers. The cost for a 3Kwh Li-ion battery was included as a part of the battery swapping cost, which was 1.84 USD per charge. This high IRR was due to the high mileage of 157 km/day and good fare box collection made possible since the e-motos were running on existing routes of ICE moto taxis. The e-moto IRR is far better in comparison with the IRR of only 12.2% of the ICE moto.

The e-moped in Hanoi was the other demo of a 2-wheeler, and here, the purchase price was € 1,032 per moped and included the cost of a much smaller battery of around 1 kWh. The mopeds also had a much lower mileage per day (30.9 km), since they were catering only to customers taking the shuttle bus to the shopping mall. The e-mopeds were not found to be commercially viable due to the low mileage and high operating costs, especially staff salaries. However, by improving mileage and thereby revenues the project can achieve a break even.

The Kathmandu shuttle van is the only vehicle with a negative IRR. The expected number of 100 passengers per day (tourists visiting the cities World Heritage sites) is insufficient to support the commercial operation of a vehicle worth € 17,820 (NPR 2,525,000 as of 31 December 2022). If, however, the Bhaktapur municipality decides to offer this service anyway, with a CER of 31 NPR/passenger, the newly designed vehicle exhibits a much better CER than the existing electric open van deployed in a similar service that costs 86 NPR/passenger.

The bus conversion involves converting an old diesel-powered vehicle through installing an electric drive system (motor, transmission, and rear axle) on the existing chassis. The conversion will be performed locally using imported components. The conversion with a 56 Kwh battery will cost € 62,000 (approximately NPR 8,507,500 as of 31 December 2022). The bus will run 96 km/day (3 trips of 32 km each) with overnight and opportunity charging. Under these conditions, an investor can expect an IRR of 8.8%, below the discount rate of 10%. However, if economies of scale can be achieved through volume manufacturing, the reduced cost (by about 20%) can lead to an IRR of 14.86%, about the same with that of a new e-bus purchased, however, at a significantly higher cost € 96,000 (approximately 55% higher). For comparison purposes, a new diesel bus exhibits an IRR of 30.12% at a much lower investment (5 million NPR).

4.2.3. Environmental attributes

The UNEP e-Mob calculator is used to analyse the impact of SOLUTIONSplus interventions on GHG emissions and air pollution in Dar es Salam and Kigali. The GHG emissions are calculated well-to-wheel (including CO2 emissions in electricity production); however, NOx and PM2.5 are based on a tank-to-wheel basis. As the e-motos in Kigali and e-Bajaj in Dar es Salaam replace old ICE vehicles, they result in significant GHG emission reduction of 73% and 76%, respectively, from the base case technology in the base year. In Hanoi, the e-mopeds can reduce CO2 emissions by 87% from the baseline technology. In terms of NOx and PM2.5 emissions, the reductions are 100% from the base case since EVs have no tailpipe emissions. However, the absolute NOx and PM2.5 reductions decline with time since there is improvement in the emission standards for ICE vehicles as well e.g., NOx emission reduction in a year from 24 e-motos in Kigali declined from 113.6 kg in 2023 to only 68.9 kg in 2033.

In Kathmandu, no major environmental impact is expected from the two 3Ws (the remodelled Safa Tempo and the smaller new design), as they replace an older electric vehicle (Safa Tempo). However, for the newly designed shuttle van, the equivalent existing ICE vehicle is a microbus run on diesel. The yearly CO2 emissions of this microbus and for the same mileage are estimated at 15.1 tons and the corresponding NOx and PM2.5 emissions are 70.1 and 24.2 kg/year. Similarly, for the bus conversion, the equivalent existing ICE vehicle is a bus run on diesel. The yearly CO2 emissions of this bus and for the same mileage are estimated at 15.1 tons and the corresponding NOx and PM2.5 emissions are 201.3 and 52 kg/year respectively. In Kigali, for the eBuses the base case technology is a diesel bus. The yearly CO2 emissions (in 2023) of this bus and for the same mileage are estimated at 57.9 tons and the corresponding NOx and PM2.5 emissions are 255.1 and 9.2 kg/year respectively. However, due to improvements in vehicle stock with time (on account of improved fuel standards) the emissions would decline especially for NOx and PM2.5. For example, in 2033 PM2.5 emissions from a diesel bus would come down to only 1.1 kg/year.

4.2.4. Concluding remarks on EVs for passenger transport

The pilots under the SOLUTIONSplus project are mostly paratransit electric vehicles (EVs), an essential transport solution in developing and emerging countries, where a large section of the population depends on these modes of transport for their daily travel. Therefore, most countries are testing out electric vehicles as paratransit mobility options, and the local priorities are also set around getting the project viable and having appropriate institutional frameworks to ensure scaled up projects. As most of these initiatives will be run by private operators, it is important that they are financially viable, and most SOLUTIONSplus pilot operations have shown that these are good options financially. The option with a negative IRR was the Katmandu shuttle van, where the expected passengers were not enough to make the option viable however compared to the existing option (an open-type electric shuttle van) it has a better CER. Converting an old diesel bus into an electric bus can be commercially viable only if significant scale economies can be achieved.

Moving to electric vehicles from ICE vehicles is expected to deliver significant GHG mitigation and benefits in abating air pollution when they are replacing vehicles that are running on fossil fuels. However, when the intervention involved replacing an existing electric vehicle such as a Safa Tempo in Kathmandu the environmental benefits were not registered.

The SOLUTIONSplus objective is to promote sustainable mobility through electric mobility, done via pilot projects of prototypes produced and developed by local firms. The project's impact assessment process uses financial cost-benefit analysis (CBA) and multi-criteria decision analysis (MCDA) to examine potential impacts on all sustainability pillars. The purpose here is also to build a wider project that considers local stakeholders' values, goals, and viewpoints. The project as was envisaged provides early findings, focusing on the financial evaluation of the choices and local community priorities.

Electric vehicles cost more upfront but are more lucrative in the long term and offer considerable financial and environmental advantages. Most countries are in the process of creating an enabling environment where electric mobility initiatives like the ones proposed here can incubate. It is imperative that these processes continue leading to a proper policy and institutional environment and establishing charging infrastructure, creating rules that enable manufacturers (technical standards, licensing, etc.) and guarantee the deployment of safe and robust vehicles, and educating drivers and users to promote e-vehicles as last-mile connections.

4.3. COMPARATIVE ANALYSIS OF CITY-SPECIFIC FREIGHT EVS

Despite its vital role in meeting the daily needs of more than 55% of the global population that lives in cities today (UN, 2019), urban freight transportation is associated with significant externalities, such as adding to the traffic congestion, conflicting with other road users (often due to limited parking and (un-) loading facilities) and significant air quality, noise and road safety issues (ITF, 2022; Marcucci et al., 2021). The frequent land use conflicts and inadequate regulation, maintenance and management of the vehicle stock and road infrastructure in developing countries aggravate these problems. Light-duty electric freight vehicles (LEFVs) offer a potential solution to these challenges, particularly those concerning the environmental implications of last-mile urban delivery services (ITF, 2023; Katsela et al., 2022).

SOLUTIONSplus has included eight LEFV-related demonstration activities in Asia, Africa and Latin America. All these prototypes, which consider local conditions and priorities and are co-developed by local manufacturers, will be examined here:

- **Remodelled Safa Tempo for cargo** (Kathmandu). Safa Tempos are electric 3Ws built in late 1990s for passenger transport. A remodelled Safa Tempo demonstrates the possibility of expanding the vehicle's utility to freight transport while replacing a conventional ICE petrol-powered truck, such as the popular Tata Ace pickup.
- **New e-3W cargo design** (Kathmandu). The cargo version of a mini Safa Tempo modular e3W design, easily customised to a passenger, cargo, or waste collection operation. Seen as an alternative to the petrol-powered pickup truck.

- **New e-4W design for waste collection** (Kathmandu). Currently, Lalitpur Municipality uses a petrol-powered 3W with open trunk to collect waste, subsequently transferring it to larger containers for disposal. The new e-4W prototype is a closed design that will offer improved hygiene and environment-friendly services.
- **Converted pickup truck** (Kathmandu). Aims to electrify the widely used petrol-powered pickup truck.
- **E-quadricycle** (Pasig). Powered by high quality electric motors and second-life batteries from Europe, this novel shared multi-purpose EV aims to replace existing ICE-powered all-purpose vehicles.
- **E-bike** (Dar es Salaam). Pedal-assist electric bicycles aimed at replacing ICE-powered motorcycles for the delivery of medical supplies to a local hospital among other uses[8].
- **E-cargo bike** (Quito). Aligned with the vision of a pedestrian-friendly low-emission zone in the historic center of Quito, e-cargo bikes were tested as re-placements for motorcycles (courier services), cars (restaurant) and manual carts (recycling associations and stevedores from a local market).
- **E-cargo bike** (Montevideo). E-cargo bikes of two different configurations (a 2W and a 3W option) were tested through a platform (mobile app) as replacements of common bicycles without pedal assistance.

As shown in Table 14, which summarises the KPI weights assigned by the stakeholders of the five demo cities of interest, project finances hold on average the top position with a share of 18.87%, followed by environment (17.49%) and society (16.32%). Hence, the comparison of the above LEFVs will be focused on these three aspects.

4.3.1. Financial analysis

The financial performance of the project vehicles is assessed either through the Net Present Value (NPV), Internal Rate of Return (IRR), and payback period for revenue-earning operations, or the Cost Effectiveness Ratio (CER) otherwise. For simplicity purposes, it was decided to restrict the analysis to IRR. Furthermore, and in order to exclude tax-related effects, the discussion is based on before-tax returns. The expected IRRs for six project vehicles are shown in Figure 11. They denote returns on investment associated with the acquisition of the demo vehicle exclusively through own funds, and its operation according to an operational profile typical for the vehicle type examined in the corresponding demo city. Two additional vehicles will be assessed through the CER approach.

8 The analysis on this vehicle is only interim, and does not appear in the Dar es Salaam report (Vol. 6).

Table 14: KPI weights for the demo cities (stakeholders' input)

		Kath.	Paris	Dar	Quito	Mont.	*Avg.*
Project finances	Financial viability	12.25	9.46	8.75	9.23	10.15	*9.97*
	Availability of finance	11.19	8.29	7.25	9.12	8.67	*8.91*
	Project finances, total	*23.44*	*17.75*	*16.00*	*18.35*	*18.82*	*18.87*
Institutional framework	Coherence with plans/goals	5.86	5.12	5.32	5.07	5.76	*5.42*
	Alignment with legislation	5.40	4.72	4.48	4.87	5.58	*5.01*
	Ease of implementation	6.39	5.25	4.50	5.27	5.09	*5.30*
	Institutional framework, total	*17.65*	*15.09*	*14.30*	*15.21*	*16.43*	*15.74*
Climate	Effect on GHG emissions	13.19	17.25	16.20	16.65	16.40	*15.94*
Environment	Effect on air pollutants	6.37	6.72	4.97	6.88	6.23	*6.25*
	Effect on noise	4.26	6.55	4.73	5.81	5.40	*5.35*
	Effect on resource use	4.84	6.62	7.20	5.94	4.92	*5.90*
	Environment, total	*15.46*	*19.88*	*16.90*	*18.63*	*16.55*	*17.49*
Society	Effect on accessibility	2.04	1.82	2.86	2.37	2.38	*2.29*
	Effect on affordability	2.16	1.75	2.01	2.35	2.05	*2.06*
	Effect on travel time	1.38	1.75	2.57	1.89	1.96	*1.91*
	Effect on road safety	1.60	1.78	2.20	2.38	2.50	*2.09*
	Effect on charging safety	1.79	1.71	1.85	1.85	2.30	*1.90*
	Effect on security	1.23	1.63	2.01	1.91	2.10	*1.78*
	Effect on well-being	1.68	1.81	2.32	2.35	2.37	*2.11*
	Effect on service quality	1.94	1.92	2.48	2.22	2.37	*2.19*
	Society, total	*13.81*	*14.15*	*18.30*	*17.32*	*18.03*	*16.32*
Wider economy	Effect on budget	6.09	6.33	5.68	4.63	4.47	*5.44*
	Effect on external trade	5.64	4.15	5.83	4.06	3.36	*4.61*
	Effect on employment	4.71	5.39	6.79	5.15	5.94	*5.60*
	Wider economy, total	*16.44*	*15.87*	*18.30*	*13.84*	*13.77*	*15.64*
	Grand total	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*

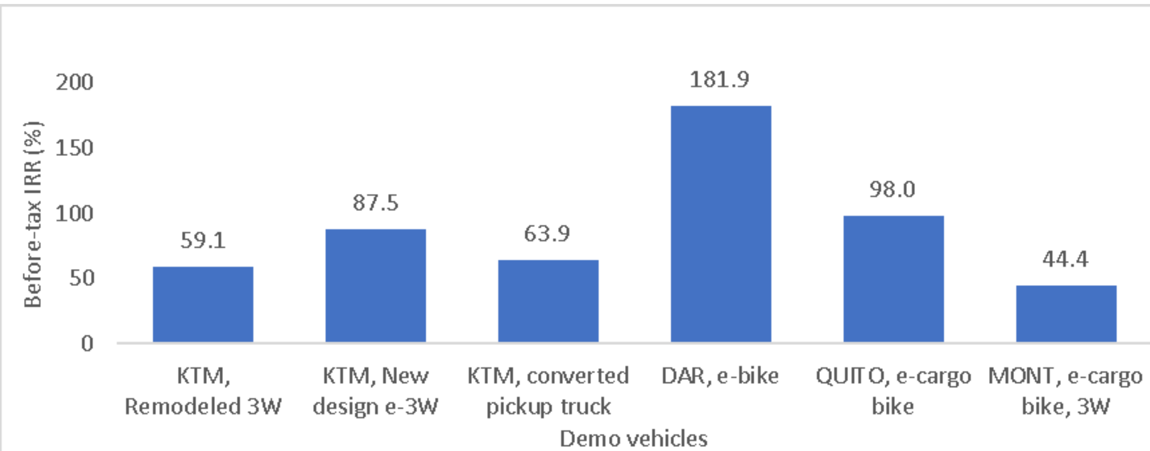


Figure 11. Before-tax IRR (%) – Investor's perspective

Due to the iterative design process followed, all vehicles exhibit a healthy financial performance, reaching the impressive rate of 181.9% for the Dar es Salaam e-bike. It is worth noting, however, that the returns of the African and Latin American vehicles are associated with 2W and 3W pedal-assist e-bikes of very low capital expenditures, which tend to be very sensitive to demand projections.

The Dar e-bike costs about € 770 ($ 820) and its Figure 11 performance assumes an average of 9.7 daily deliveries, which is the current production of an ICE motorcycle used by the targeted hospital. This can only be achieved if the customer base is expanded, a digital order/fleet management system is introduced, and the e-bikes are equipped with a second battery to be swapped during the day. In the absence of this second battery, only 6 daily deliveries are possible, and the IRR drops dramatically to -1.1%.

At a cost of € 3,090 ($ 3,300), the performance of the 3W e-cargo bike of Montevideo is the lowest among the vehicles compared, albeit still quite healthy. Furthermore, it is characterized by lower uncertainty, as it is based on an average of 9.5 trips per day, a figure supported by the trial period results, achieved through an existing delivery platform using traditional bicycles. Under a similar operational profile, the 2W version can be even more profitable due to a lower capital cost (€ 2,400). It is worth noting, however, that the productivity of the e-cargo bikes lagged 18% behind that of common bicycles due to maneuverability problems, while the cargo consolidation possibility they offer was not exploited during the trials.

With a € 2,630 ($2,800) investment, the Quito Long John e-cargo bike generates a return of 98.0% when performing 8 short trips within the historic centre of the city. Other configurations tested in Quito proved much more cost effective than a petrol-run car serving a local restaurant, and also more effective than manual carts used for recycling waste due to significant increases in productivity (the project's impact assessment survey showed that the recyclers increased their monthly income by 25%). The Kathmandu vehicles are larger. With a 10kWh LiFePO4 battery, the € 9,920 newly designed 3W offers a return of 87.5% when performing 3.5 trips/day on average. For comparison purposes, a new petrol-driven pickup truck, costing € 13,900, generates a return of 44.9% under identical operations.

A cargo 3W was also produced through remodelling an existing 'Safa Tempo.' Safa Tempos are electric passenger 3Ws that were constructed in late 1990's and are approaching the end of their useful life. In addition to replacing the passenger cabin with a cargo platform, the remodelling included replacing the old lead-acid battery with a li-ion 23 kWh set. Over the useful life of 6 years, the required investment of € 13.720 is expected to produce a return of 59.1%. Seen from a Safa Tempo operator's viewpoint, however, the picture differs. Until the expiration of its license, an existing Safa Tempo is expected to make a pre-tax profit of NPR 1,280,000. This constitutes earnings foregone for the operator who decides to remodel their vehicle. After accounting for this additional cost, the IRR of the remodelling drops to 41.3%, which is still quite attractive.

The conversion of a 15-year old petrol-driven pickup truck, worth about € 3,170, to electric was also tested in Kathmandu. The € 13,560 total investment leads to an IRR of 63.9%. However, during the remaining 6 years of its life, this vehicle is expected to produce a NPV of about NPR 3.5 million (at a discount rate of 10%). After considering this foregone profit, the pickup operator is expected to make a further profit of NPR

737,000 before-tax on the conversion, equivalent to a 14.9% return.

In relation to non-revenue-earning operations, the design of the new e-4W waste collector in Kathmandu has been optimized to achieve 495 NPR/m3. of waste collected, 13.5% lower than the CER of the petrol-powered 3W currently used by the Lalitpur municipality. At 55.76 PHP/vkt, the cost savings achieved by the Pasig e-quad against the existing ICE vehicles that move primarily medicines to/from public health facilities for the City Health Department are even more impressive (25.72%).

4.3.2. Environmental and social attributes

In Kathmandu, no major environmental impact is expected from the remodelled 3W, as it replaces an older e-vehicle. This is not the case, though, for the newly designed 3W and the converted truck, both of which will typically replace a petrol-driven pickup. The yearly CO2 emissions of this vehicle for similar mileage are estimated at 5.8 tonnes on a well-to-wheel basis. The corresponding NOx and PM2.5 emissions (on a tank-to-wheel basis) are 26.5 and 36.4 kg/year respectively. Given that almost all electricity production in Nepal is hydro-based, it can be safely assumed that the above figures constitute the emissions abated by each unit of the newly designed 3W. When it comes to the waste collector, a factor of 0.6926 should be applied on the above emissions to cope for the lower mileage of this vehicle in comparison to a pick-up truck. In relation to societal impacts, figures have been compiled only for the remodelled Safa tempo, the prototype of which has already been tested. The drivers interviewed found significant improvement in comparison to an ICE-run pickup in terms of noise and drivability, and slight improvement in accessibility, comfort and safety. The old solution was found easier to charge/refuel though. No impact on road safety was foreseen by the experts interviewed. In relation to institutional issues, the lack of technical standards for electric vehicles and the frequent rotation of public servants in Nepal hinder the promotion of e-mobility in the country.

In Pasig, the commercial ICE vehicle to be replaced by the project e-quad emits 428.57 gCO2/km and 0.064 gNOx/km against 70.11 gCO2/km and 0.00 gNOx/km of the e-quad respectively. The e-quad was favoured for its ease of driving and compatibility for first-/last-mile operations due to its capability to travel narrow roads. However, the e-quad scored unfavourably in terms of suitability of adverse weather conditions (battery is prone to get wet during flooding), travel comfort (lack of air-conditioning), security (parts can easily be stolen), and continuity of journey chains. In relation to institutional issues, uncertainties in alignment of the regulatory framework at the national and city levels (e.g., regarding the extent to which EV types are allowed on certain roads) hinder the promotion of e-mobility in the demo city.

The e-cargo bikes of Montevideo are tested against traditional bicycles, leading to a higher carbon footprint that depends on the carbon intensity of the grid electricity. In general, their carbon emissions are much lower than those of an ICE van (23.6 vs. 389.0 gCO2e/km), which also applies on NOx emissions (0.066 vs. 1.794 gNOx/km) (Fraselle et al., 2021). In Quito and Dar, the project LEFVs aim to replace gasoline motorcycles, which emit 59.9 gCO2, 0.26 gNOx and 0.1 gPM2.5 per km (Farquharson, 2019). The corresponding emissions of the e-bikes depend on the source of electricity generation but can be much lower, ranging from 1:5 for CO2 to 1:40 for PM2.5 emissions (Farquharson, 2019). The lack of proper parking areas and bike lanes is a challenge for these lighter vehicles, particularly for e-cargo bikes that have difficulties moving to/from the sidewalks. Security is an additional concern for these vehicles, as cargo can remain unattended while the driver delivers a package. Safety has been identified as a major concern for all electric bikes tested.

4.3.3. Concluding remarks on light-duty freight EVs

LEFVs prove a popular solution for last-mile urban deliveries, particularly in developing countries such as those of the SOLUTIONSplus project, due to their flexibility, small dimensions and low investment requirements. All vehicles tested exhibit a healthy return on investment, meaning that no financial support is required for their promotion. However, the lighter vehicles such as the e-bikes of Dar es Salaam and the e-cargo bikes of the Latin American cities appear very sensitive to demand forecasts. A well-functioning distribution network (probably supported by a digital management scheme) and integration services (exploiting the consolidation possibilities of e-cargo bikes) are necessary for the efficient operation of LEFVs, leading towards collaborative business models according to the 'broader EV uptake' approach (ITF, 2023). Furthermore, and in order to deploy them effectively, cities need proper planning for infrastructure (both for accommodating the rather bulky e-cargo bikes and for charging), supporting regulatory framework and policies for manufacturing (e.g., technical standards, licensing, etc.), and awareness raising among drivers.

Conversions of existing vehicles are generally profitable albeit at lower return rates. In general, however, the old fossil-fuel-driven solutions are also profitable depriving operators of running vehicles from sufficient motivation to convert. As such, conversions at scale can be expected only at the end of the useful lives of existing vehicles.

4.4. POTENTIAL OF MAAS IMPLEMENTATION

Mobility as a Service (MaaS) is a new transport and mobility concept that integrates existing and new mobility services (NMS) into a single digital platform, providing customized mobility options and offering personalized trip planning and digital payment possibilities (Jittrapirom et al., 2017). MaaS has the potential to improve the travelling experience, reduce travellers' costs, efficiently manage travel demand, and improve environmental and social outcomes consumption (Jittrapirom et al., 2017; Sochor et al., 2015). MaaS has been gaining popularity in Europe / the Global North and has been implemented in several cities (Figure 12) with positive results related to sustainable and low-carbon mobility (Sochor et al., 2015).

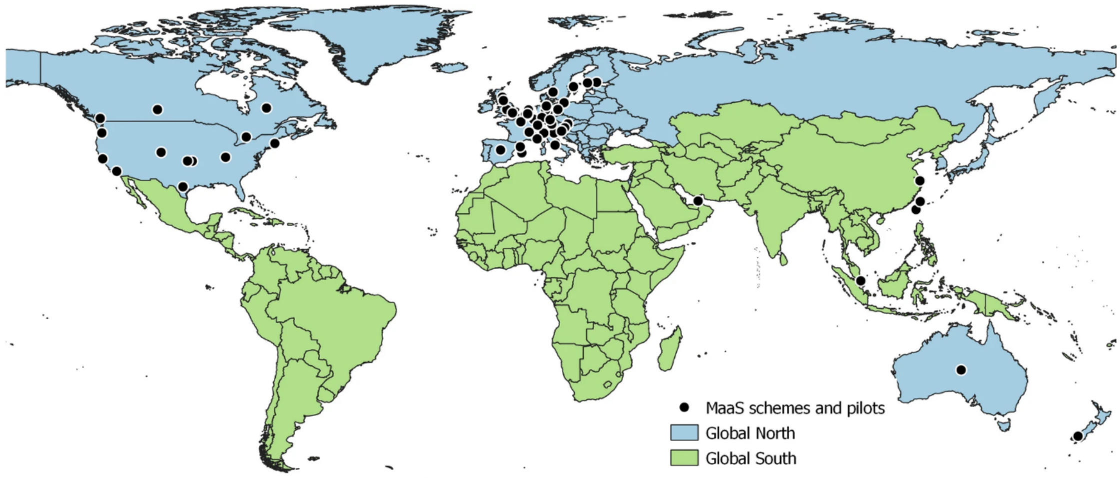


Figure 12. Worldwide penetration of MaaS schemes as of 2019 (Data source: MaaS-Alliance)

However, in developing countries, in contexts of fragmented and often informal public transport systems, lack of data, cash economies, low digitalization levels, the implementation of such a concept comes with a lot of challenges (Hasselwander and Bigotte, 2023). While important scholarly contributions have been made to understand the barriers and enablers of MaaS (Butler et al., 2021; Karlsson et al., 2020; Matyas and Kamargianni, 2021), these studies primarily rely on literature reviews and expert interviews, and have mainly focused on the European context. The SOLUTIONSplus project offers the unique opportunity to complement these findings with data and insights from real-world MaaS schemes in the global South.

The SOLUTIONSplus project included the provision of a white label app customizable to the needs of the cities to enable access to the e-mobility services for the end-users as part of its offer to its seven[9] demonstration cities in Asia, Africa and Latin America. In a MaaS approach, the app offered the integration of all services, payment and information useful for the end-users allowing the possibility of integrating e-bikes, e-3-wheelers, e-taxis, etc. to the existing public transport (PT) system.

This allows us to define and analyse the enabling conditions needed to adopt the MaaS concept in developing countries and assess its potential. The analysis starts by classifying the MaaS level and the implementation process in the seven SOLUTIONSplus demo cities. The analysis of the enabling factors focuses on Kigali, Kathmandu and Quito, the three cities in which the feasibility of implementation of a MaaS app in the context of the project was further explored.

4.4.1. MaaS level and pilot implementation in SOLUTIONSplus cities

In an attempt to create a comparison tool for the level of penetration of the MaaS concept in different cities, Sochor et al. (2018) propose a topology that consists of 5 levels based on the degree of integration, i.e.: 0 - no integration; 1 - integration of information; 2 - integration of booking and payment; 3 - integration of the service offer; 4 - integration of societal goals. As shown in Table 15, the seven SOLUTIONSplus cities fall between the Levels 0 (in transition to 1) and 2. This means that most cities already have access to some sort of route planning app and the more advanced ones are already in the process of integrating the in-app payment functionality.

Table 15. MaaS level and implementation in SOLUTIONSplus cities

CITY	MAAS LEVEL	LEVEL OF MAAS IMPLEMENTATION UNDER SOLUTIONSPLUS
Africa		
Kigali	L1	Discussions between the SOLUTIONSplus team and the representatives of the City of Kigali to develop a customized MaaS app took place between July 2021 and May 2023. However, a joint decision not to pursue it due to high constraints and limited time was taken.
Dar es Salaam	L0 in transition to 1	Dar es Salaam is developing its own planning and ticketing app for which the SOLUTIONSplus team had an advisory role. The conditions to implement a MaaS app between BRT buses and paratransit modes are not in place yet.

9 The Nanjing demo was excluded from the analysis, as it focusses on a different concept.

CITY	MAAS LEVEL	LEVEL OF MAAS IMPLEMENTATION UNDER SOLUTIONSPLUS
Asia		
Kathmandu	L0 in transition to 1	After a prefeasibility assessment conducted by DTU (Ortving and Brodthagen, 2022), it was determined that the conditions to implement a MaaS app were not yet in place in Kathmandu (absence of a properly organized transport system, need for a different business model, and regulations incentivizing transport operators to participate in a MaaS platform).
Hanoi	L2	It was decided to put all efforts in the development of a booking app for the e-2-wheelers being implemented in the pilot.
Pasig	L1	The governance of PT in Pasig would have required the involvement of a larger number of stakeholders, including the national government. Due to the complexity, after the assessment it was decided not to pursue it.
Latin America		
Montevideo	L1 in transition to L2	The Municipality of Montevideo declined the offer arguing that they already have their own municipal app called "Como ir", which at the moment only allows trip planning, but is supposed to integrate in-app payment once the ticket validators in the buses are replaced.
Quito	L1	A customized MaaS app including a trip planner, in-app payment and e-ticketing was developed in close collaboration with the municipal PTOs (BRTs and subway). In order to address the specific needs of the city, two complements were added: 1) a web app to top up the e-wallet with cash in the ticket booth and 2) A mobile app to validate the e-tickets until the automatic turnstiles are procured and installed in all stations. The 3 apps were piloted in Q4 2022 with 50 university students for a period of 4 weeks in 1 BRT station. The circumstances that led to the pilot implementation in Quito were: 1) the imminent launch of the subway line, by which the city is in the process of modernizing and integrating the PT system, which encompasses the Integrated Payment System (SIR), the Data Exploitation System (SAE) and the User Information System (SIU). The Municipality was reluctant to continue and scale-up the pilot due to the lack of knowledge of the new authorities about the MaaS concept, the regulatory framework for its implementation and the linkage to and benefits for the SIR. The main concerns were related to the business model and costs after the project end, as well as the ownership of the data and the application.

Regarding the level of implementation under the SOLUTIONSplus project, it is shown that despite having the possibility of testing the customized app free of charge for the duration of the project, only 2 out of 7 cities, Quito (Ecuador) and Kigali (Rwanda), started and continued the process. Yet only Quito was able to test the customized app in real operations. Nevertheless, it is worth noting that other demonstration cities such as Hanoi, Dar es Salaam and Montevideo have taken their own path to develop mobility apps for specific needs.

4.4.2. The enabling environment in Quito, Kathmandu and Kigali

A literature review was conducted to investigate the main requirements, but also the barriers that have been defined/identified both in the Global North and South for the implementation of the MaaS concept (Butler et al., 2021; Karlsson et al., 2020). Based on that and following the methodology applied by Hasselwander and Bigotte (2022), the technology, organisation, and environment (TOE) framework was used to classify what from now on will be called enabling factors. A total of 20 variables have been identified as enabling factors for MaaS implementation. The elements considered under Technology refer to the level of digitalization in the selected cities. In terms of Organisation, enablers such as policies, plans and the governance structure related to digitalization of transport and intelligent transport systems were analysed. Under Environment, the enabling factors are related to the integration level of the public transport system and other transport services.

The results of the analysis using the TOE framework are summarised in Figure 13, Figure 14, and Figure 15. As it can be seen, only very few factors are fully met in the three cities. Nevertheless, in most factors Quito, Kathmandu and Kigali comply partially, which means there is already some level of advancement. A detailed discussion follows below.

The technological dimension

In the urban environments of Quito, Kathmandu, and Kigali, the transition towards MaaS is heavily influenced by technological factors. A key consideration is the accessibility of smartphones and mobile internet, which serves as the entry point for MaaS adoption. While these cities have partial access to smartphones and mobile internet, the affordability of data plans remains a challenge for many residents. Despite this, there are signs of progress as digital connectivity continues to improve, offering hope for broader adoption of MaaS solutions.

City	Quito	Kathmandu	Kigali	In summary
Enabling factor	Expert Assessment			
Access to smartphones and mobile internet	PARTLY	PARTLY	PARTLY	Access to a smartphone doesn't seem to be a barrier, at least not in the age group expected to use the app, and not in urban areas. Mobile internet access has risen in these cities, but the affordability of data plans still represents a restriction for an important percentage of the population.
Availability of payment gateways (e.g.: PayPal)	PARTLY	PARTLY	YES	MTN Mobile Money is widely used for transport services in Kigali. In Kathmandu and Quito there some payment gateways, such us e-Sewa and DeUna, but their use for transport services is limited or non-existent.
Penetration of mobility apps (e.g.: Uber) 1) Availability and use 2) In-app payment (credit card usage, payment gateways, etc.)	YES	YES	YES	There are, however, several mobility apps, local and international, operating in the 3 cities. However, the possibility to pay in-app with credit / debit cards or payment gateways is still limited in most cases.
Availability of journey planner (e.g.: Google maps, Waze, municipal apps, etc.)	PARTLY	PARTLY	YES	Global apps such as Google maps work in the 3 cities. However, with different functionalities. While in Quito and Kigali it is possible to see the bus routes and the estimated times, in Kathmandu it only shows the walking route.
Users' acceptance and profile	PARTLY	PARTLY	PARTLY	There positive experiences of the widespread use of mobile money and e-wallets in Kigali and Kathmandu. It is expected, as in other contexts, that the primary target group is young people. However, depending on the user friendliness, affordability and benefits of using the app, a larger and more diverse number of users could be attracted.
Data collection and standards 1) Standardization and aggregation of data, open data or willingness to share data 2) Real-time data collected 3) GTFS files available	PARTLY	NO	PARTLY	The use of ITS by PTOs is still quite limited / fragmented. (Real-time) data collection, sharing and ownership is still an unresolved issue in the 3 cities.The only city from the 3 with a GTFS available was Quito.
Privacy and security of user data is not a limitation for users	YES	YES	PARTLY	Concerns regarding data privacy / security in the general population of these cities is low in comparison with European countries / cities. In the case of Kigali, however, the privacy and security of user data are quite relevant for the national authorities.

Figure 13. Technology enabling factors in Quito, Kathmandu and Kigali

Payment gateways also play a crucial role in shaping MaaS adoption. Kigali stands out for its widespread use of MTN Mobile Money for transport services, while Kathmandu and Quito have limited or non-existent options like e-Sewa and DeUna. This diversity underscores the need for tailored solutions that cater to the unique circumstances of each city. This domain also opens much space for collaboration with digital payment providers which could be interested in further pushing the MaaS concept.

The proliferation of mobility apps is another significant aspect of the digital landscape in these cities. From local startups to international players, a variety of apps aim to streamline transportation. However, while these apps are widely available, the ability to make cashless transactions within them remains limited. Google Maps, for instance, has made its way into all three cities, albeit with varying levels of functionality. While Quito and Kigali offer comprehensive bus routes and estimated times, Kathmandu provides only walking routes, reflecting the different infrastructural realities of each city.

The acceptance and profile of MaaS among potential users in developing cities is influenced by factors such as age, accessibility, and perceived benefits (Hasselwander et al., 2022). While younger residents in Kigali and Kathmandu show positive experiences with mobile money and e-wallets, broader adoption depends on factors like usability, affordability, and perceived benefits.

Data collection and standards present challenges, with Quito leading the way with its available GTFS files, a standardized and commonly used format that contains static or scheduled information about the city's public transport services. However, the use of ITS infrastructures by public transport operators remains limited, hindering real-time data collection and sharing. Privacy and security concerns are relatively low in Quito and Kathmandu, but significant in Kigali, where national authorities prioritize the protection of user data.

In summary, while there are technological enablers for MaaS in Quito, Kathmandu, and Kigali, challenges such as limited payment options, data collection standards, and privacy/security concerns need to be addressed for broader adoption and success of MaaS initiatives.

The organisational dimension

Several organisational key factors emerge that shape the feasibility and progress of MaaS initiatives in Quito, Kathmandu, and Kigali.

City	Quito	Kathmandu	Kigali	In summary
Enabling factor	Expert Assessment			
Transport digitalisation policy objectives	PARTLY	PARTLY	PARTLY	The 3 cities analyzed have some type of plan, framework or strategy either at the national or local level, where the use of ICT to improve public transport is mentioned. The MaaS concept, however, is only explicitly mentioned in Quito's SUMP, yet without further detail.
General transport authority / degree of centralization / governance	PARTLY	NO	NO	There's not a unique authority. Transport governance is pretty disperse. Quito is trying to create a general transport authority, but the process will take time.
Knowledge & capacities 1) Experience / Clarity regarding role and responsibilities / expected benefits 2) ICT expertise	PARTLY	NO	NO	There's lack of knowledge / clarity about the MaaS concept, its application, operationalisation and benefits. In the case of Quito, however, we counted with the support of a public official that had clarity about the concept and benefits. It was one individual, at the institutional level it's still an unknown concept.
Transport authorities structures, fast decision processes, innovative strategies and integrated planning approaches	NO	NO	NO	The complexity of transport governance, including the relationship between public and private actors, and the low speed of processes, makes the introduction of MaaS difficult.
Political will and institutionalization 1) Top management support 2) Public sector engagement / Political support 3) Necessity of a window of (political) opportunity / political cycle	PARTLY	YES	YES	In general terms, these municipalities were engaged. The processes in these 3 cities were able to move forward only because of the top management support provided. However, the system and the governance is not mature enough for its full implementation. In the case of Quito, the political cycle played a huge role, as the new authorities were not as supportive of the project as the previous ones.
Financial resources and funding	PARTLY	NO	NO	The municipalities didn't have their own resources because MaaS is not yet in their priorities / radar. In Quito, there are resources as the Integrated Payment System (SIR) is being implemented as part of the PT modernization.
Clarity about the business model / ownership of app / data collection	NO	NO	NO	Business model and data ownership are among the main concerns when deciding to move forward. There was very little knowledge in the counterparts about how to implement the MaaS concept in the given environment.
Enabling regulatory framework	PARTLY	PARTLY	PARTLY	At the moment, the regulations in the analyzed countries are either at a very early stage or very restrictive. In particular, we encountered some regulations that make the collaboration with international companies for the development of MaaS or other mobility applications difficult. In Rwanda, for instance, cloud storage can't happen outside of the country. In Ecuador, on the other hand, the fare collection of PT has to be in the corresponding bank account of the PT authority within 24hours.

Figure 14: Organisational enabling factors in Quito, Kathmandu and Kigali

Firstly, transport digitalization policy objectives serve as a foundational element. While all three cities have outlined plans or strategies at either the national or local level to leverage ICT for public transport improvement, only Quito's Sustainable Urban Mobility Plan (SUMP) explicitly mentions the MaaS concept, albeit without detailed elaboration. Considering the limited success of commercial MaaS schemes, we highlight the essential role of the public sector and the need to prioritize multimodality and digitalization in transport, which are key for MaaS uptake.

The degree of centralization and governance in transport authorities significantly influences MaaS implementation. Quito is making strides towards establishing a general transport authority, but the process is gradual, and overall governance remains decentralized and fragmented in all three cities. This can significantly hamper the development of transport innovations such as MaaS as highlighted in previous research (Hasselwander and Bigotte, 2022). On a related note, also knowledge and capacities within transport authorities are essential for effective MaaS development. However, there is a notable lack of clarity and expertise regarding the MaaS concept and its operationalization, except for isolated instances of support from individual officials, particularly in Quito.

Transport authorities' efficient structures, decision-making processes, and planning approaches are crucial for MaaS success. Unfortunately, the complexity of transport governance and the slow pace of decision-making hinder the introduction of innovative strategies like MaaS across all three cities. This has been commonly observed in

Global South cities and already prevented the introduction of other sustainable mobility solutions such as BRT or cycling lanes. In this context, also political will plays a pivotal role. While there is general engagement from municipal authorities, full implementation is hindered by immature governance structures and changes in political leadership, as seen in Quito's experience.

Moreover, MaaS is also not yet a priority for municipal budgets in these cities, resulting in limited resources allocated to its development and implementation. Clarity about the business model and ownership of the MaaS app and data collection is another significant challenge. There is a lack of understanding and consensus among stakeholders about these crucial aspects, posing barriers to progress.

Finally, the enabling regulatory framework is essential for facilitating MaaS implementation. Currently, regulations in the analysed countries are either in nascent stages or overly restrictive, posing challenges for collaboration with international partners and the development of MaaS applications.

The business environment dimension

In the business environment context of MaaS implementation, integrated and regulated operator landscapes form a foundational element for MaaS implementation. While all three cities have some form of route service contracts to formalize and regulate transport, which is an advantage compared to most Global South cities, the level of integration varies, with Kathmandu facing significant fragmentation due to high levels of informality in transport services.

Private sector engagement and support from transport groups are crucial for MaaS development. While opposition has not been substantial, incomplete public transport integration in Quito and Kathmandu may lead to some resistance from transport operators, which previous research has also identified as a major barrier for MaaS implementation in developing cities (Dzisi et al., 2023).

Integrated payment systems for public transport are essential for MaaS functionality. Kigali leads in this aspect with a smart card system, while Quito is in the process of introducing an Integrated Payment System. However, Kathmandu has faced challenges in this regard, with cash remaining the primary payment method. Nevertheless, some alterations in the MaaS model in Global South context are conceivable, allowing also to build MaaS schemes upon cash systems and non-digital technologies (Hasselwander and Bigotte, 2023).

City	Quito	Kathmandu	Kigali	In summary
Enabling factor	Expert Assessment			
Integrated and regulated operator landscape 1) Form of Route Service contracts between Authorities and transport operators 2) Formal, multimodal and integrated PT system (physical and tariff) 3) Low informality rate in transport services	PARTLY	NO	PARTLY	In the 3 cities, there is some form of route service contracts that formalises and regulate transport. In the recent years, the 3 cities have tried to improve the processes. However, the PTO landscape is still very fragmented in Kathmandu, and partially fragmented in Quito. Paratransit / informal transport is only relevant in Kathmandu. Thus, the level of integration of the system varies, but is still not ideal in any of the 3 cities.
Private sector engagement / Support from transport groups and associations	PARTLY	PARTLY	YES	The development has not reach the level of opposition. However, the level of integration that the proper functioning of the MaaS concept requires will need important negotiations with all PTOs. Thus, in the case of Quito and Kathmandu, where PT integration is not completed, it can lead to some level of opposition.
Integrated payment system for PT	PARTLY	NO	PARTLY	Kigali has a smart card that can be used in all PT operators. Quito is currently working on the introduction of an Integrated Payment System, which will include the proper infrastructure, the IT systems and fund reconcialiations. In Kathmandu, there have been some failed attempts. In the 2 latter, cash is still the mean of payment in PT, while in Kigali mobile money is used.
Existance and integration with other transport services (bike sharing, e-scooter sharing, etc.)	PARTLY	NO	PARTLY	In the 3 cities there are transport services, be it bike sharing, e-scooters or moto-taxi services. Some of them linked to mobility / booking apps. However, there's no proper integration between other services and PT. In Kigali and Quito there are some located close to PT stations, but there's not a proper multimodality strategy.
Successful adoptions (in the country/region) serving as blue print	PARTLY	PARTLY	PARTLY	There are some mobility apps in the 3 region trying to start a MaaS service with many limitations. However, so far, in most cities they only have trip planning functionalities.

Figure 15. Environment enabling factors in Quito, Kathmandu and Kigali

Existence and integration with other transport and micro-mobility services, such as bike sharing and e-scooter sharing, are crucial for promoting multimodality. While these services exist in all three cities, especially in Quito and Kigali, there is a lack of proper integration with public transport systems, hindering seamless intermodal journeys.

Finally, the lack of successful implementations of MaaS in other regions that could serve as blueprints for potential adaptation are another issue. However, there exist some mobility apps in the countries under investigation that offer limited functionalities, primarily focusing on trip planning rather than comprehensive MaaS services. Insights from these initiatives can help for the informed planning and implementation of MaaS in Quito, Kigali, and Kathmandu, and serve as an impetus to move towards MaaS.

4.4.3. Concluding remarks on MaaS implementation

As it has been shown in the above analysis, the implementation of the MaaS concept require the fulfilment of a set of technology, organisation and business environment conditions. The MaaS level analysis shows that despite the fact that some of the analysed cities are still in level 0, they are already transitioning to level 1. Most cities are in level 1, some transitioning to level 2. Thus, the cities analysed, despite their differences, reveal a slow, but steady progress towards the adoption of the features of an intelligent and integrated transport system that will enable MaaS. There are, however, still a series of barriers that need to be overcome related to the digitalization level, as well as in the transport system and governance, before the MaaS concept implementation is feasible in developing countries. A step-by-step approach could be desirable, starting by the gradual integration of all PTOs into the system in one digital platform and then the addition of other mobility service providers.

REFERENCES

1. Barfod, M.B., 2020. Multi-criteria decision analysis exemplified in the transport sector. Technical University of Denmark, Department of Technology, Management and Economics, Kongens Lyngby, Denmark.
2. Barfod, M.B., Salling, K.B. and Leleur, S., 2011. Composite decision support by combining cost-benefit and multi-criteria decision analysis. Decision Support Systems, 51 (1), pp. 167-175 (https://doi.org/10.1016/j.dss.2010.12.005).
3. Belton, V., and Stewart, J.T., 2002. Multiple criteria decision analysis: an integrated approach, Kluwer Academic Publishers, London.
4. Butler, L., Yigitcanlar, T., & Paz, A., 2021. Barriers and risks of Mobility-as-a-Service (MaaS) adoption in cities: A systematic review of the literature. Cities, 109, 103036. https://doi.org/10.1016/j.cities.2020.103036
5. Canu, F.A., Pedersen, M.V., Garza, J.H., Trærup, S.L.M. and Dhar, S., 2020. Technology Needs Assessments: Finance Guide for Implementation of Technology Action Plans. A UNEP DTU Partnership publication, Copenhagen, Denmark.
6. Dzisi, E., Obeng, D.A., Tuffour, Y.A., & Ackaah, W., 2023. Digitalization of the paratransit (trotro) using mobility as a service: What are the adoption intentions of operators and operator unions in Ghana?. Research in Transportation Business & Management, 47, 100968.
7. Farquharson D.T., 2019. Sustainable Energy Transitions in sub-Saharan Africa: Impacts on Air Quality, Economics, and Fuel Consumption. PhD thesis at Carnegie Mellon University, Pittsburgh, PA.
8. Fraselle, J., Limbourg, S.L., Vidal, L., 2021. Cost and Environmental Impacts of a Mixed Fleet of Vehicles. Sustainability 13, 9413.
9. Goodwin, P. and Wright, G., 2014. Decision Analysis for Management Judgment, John Wiley & Sons Ltd, West Sussex, UK, 5th edition
10. Hasselwander, M., & Bigotte, J. F., 2023. Mobility as a Service (MaaS) in the Global South: Research findings, gaps, and directions. European Transport Research Review, 15, 1-16.
11. Hasselwander, M., Bigotte, J.F., Antunes, A.P., & Sigua, R.G., 2022. Towards sustainable transport in developing countries: Preliminary findings on the demand for mobility-as-a-service (MaaS) in metro Manila. Transportation Research Part A: Policy and Practice, 155, 501-518. https://doi.org/10.1016/j.tra.2021.11.024
12. IEA, 2020. Data and statistics, CO2 emissions by sector, World 1990-2018. https://www.iea.org/data-and-statistics?country=WORLD&fuel=CO2%20emissions&indicator=CO2BySector (Accessed: 30/11/2020)
13. ITF, 2023. Shifting the Focus: Smaller Electric Vehicles for Sustainable Cities.

International Transport Forum Policy Papers, No. 123, OECD Publishing, Paris.
14. ITF, 2022. The Freight Space Race: Curbing the Impact of Freight Deliveries in Cities. International Transport Forum Policy Papers, No. 109, OECD Publishing, Paris.
15. Jittrapirom, P., Caiati, V., Feneri, A. M., Ebrahimigharehbaghi, S., Alonso-González, M. J., & Narayan, J., 2017. Mobility as a service: A critical review of definitions, assessments of schemes, and key challenges. Urban Planning, 2(2), 13-25.
16. Karlsson, I.C.M., Mukhtar-Landgren, D., Smith, G., Koglin, T., Kronsell, A., Lund, E., Sarasini, S., & Sochor, J., 2020. Development and implementation of Mobility-as-a-Service – A qualitative study of barriers and enabling factors. Transportation Research Part A: Policy and Practice, 131, 283–295. https://doi.org/10.1016/j.tra.2019.09.028
17. Katsela, K., Güneş, Ş., Fried, T., Goodchild, A., Browne, M., 2022. Defining Urban Freight Microhubs: A Case Study Analysis. Sustainability 14, 532.
18. Marcucci, E., Gatta, V., Lozzi, G., 2021. City Logistics landscape in the era of on-demand economy: Main challenges, trends and factors influencing city logistics. LEAD project Deliverable D1.1.
19. Matyas, M., & Kamargianni, M., 2021. Investigating heterogeneity in preferences for Mobility-as-a-Service plans through a latent class choice model. Travel Behaviour and Society, 23, 143–156. https://doi.org/10.1016/j.tbs.2020.12.002
20. Ortving, A., & Brodthagen, M., 2022. An Analysis of Kathmandu's Public Transport System and Viable Improvements through MaaS IT solutions; A Pre-Feasibility Study. Bachelor thesis, DTU Management, Technical University of Denmark.
21. Reck, D.J., Martin, H., & Axhausen, K.W., 2022. Mode choice, substitution patterns and environmental impacts of shared and personal micro-mobility. Transportation Research Part D: Transport and Environment, 102, 103134. https://doi.org/10.1016/j.trd.2021.103134
22. Sochor, J., Arby, H., Karlsson, I. C. M., & Sarasini, S., 2018. A topological approach to Mobility as a Service: A proposed tool for understanding requirements and effects, and for aiding the integration of societal goals. Research in Transportation Business & Management, 27, 3–14. https://doi.org/10.1016/j.rtbm.2018.12.003
23. Sochor, J., Strömberg, H., & Karlsson, I. M., 2015. Implementing mobility as a service: Challenges in integrating user, commercial, and societal perspectives. Transportation Research Record, 2536(1), 1-9.
24. UN, 2019. World Urbanization Prospects: The 2018 Revision. United Nations report, New York.

Appendix A. Glossary

Assessment attribute

Generic term denoting a criterion used in assessing alternative options in a multi-criteria decision analysis application. The GHG emissions abated by an e-mobility solution, or its perceived safety are examples of such criteria. The full list of attributes entering the SOLUTIONSplus assessment appears in the tree structure of Figure 3.

Assessment boundaries

The assessment boundaries define the scope of the impact analysis. In terms of nature, the boundaries of the financial analysis ('effect of project finances' of Figure 3) are set strictly around the project implementing agency, while for all other L1 attributes, the entire society of the demonstration area serves as the boundary of the socio-economic analysis. In terms of scale, the boundaries are set as close as possible to the geographic limits of the area affected by the project. Given that impacts outside these limits cannot be ruled out, the geographic boundaries are always somewhat arbitrary. Often the boundaries are set by the sources of available data. In terms of time horizon, the analysis period is bounded by the base year (status quo) and the target year (set as the outer year for accounting project impacts).

Attribute family

In multi-level attribute trees, as is our case, the term attribute family is used to denote a group of same-level attributes sharing the same parent (the relevant attribute of the immediately higher level). For example, in the tree structure of Figure 3, 'major accidents', 'minor accidents', and 'accidents involving VRUs' form a Level 3 family under the Level 2 'road safety' parent.

Attribute scoring

The process of assigning a value to the performance of an alternative option against a specific attribute (criterion). In the context of the SOLUTIONSplus project, the scores are expressed in stars in a 5-star scale.

Attribute value

Denotes the numerical value of the indicator that corresponds to the attribute being scored. If, for example, the annual number of major accidents in one of the demonstration cities under a specific up-scaled project design is expected to be 1,800 in 2030, the value for this particular attribute will be 1,800 major accidents per year. For qualitative attributes, the attribute values can be a number on a qualitative scale or even a direct rating.

Attribute weighting

The process of assigning weights to the attributes entering an assessment. The weights define the relative importance that the decision-makers ascribe to the attributes and describe their preference structure.

Base year

Denotes the beginning of the period examined by an assessment and determines the status quo. As SOLUTIONSplus started in 2020, this is the year taken as the base year of the analysis, unless more recent data can be obtained.

Baseline scenario

Denotes the imaginary situation of the project area, as we would expect it to develop up to the target year, assuming that there is no intervention through the assessed project. The concept is used for isolating the effects of the examined project from influences caused by external factors.

Cost effectiveness ratio

Used for assessing projects/components, mainly in the public sector, where revenues either do not exist or are very difficult to monetise. It relates the costs of a project to its key outcomes or the so-called 'units of effectiveness' (e.g., number of lives saved, volume of waste collected, etc.). CER is obtained by dividing total costs by the units of effectiveness. The lower a project's CER is, the more desirable its undertaking becomes.

Cumulative weights

The cumulative weight of an attribute at a specific level indicates the importance that the decision makers assign to this particular attribute in relation to all attributes of that level. The cumulative weights of all attributes in a level sum to 100. For example, in the Kathmandu demo, the cumulative weights in the L3 road safety family are: 0.68 for major accidents, 0.46 for minor accidents, and 0.47 for accidents involving VRUs, summing to 1.60, which is the cumulative weight of the L2 road safety attribute (refer to Figure 4 in Vol. 4).

Demonstration project

Consists of the city-specific demonstration actions that were planned together with the local stakeholders either before the start or during the early stages of SOLUTIONSplus and which will be implemented by the consortium during the project life (2020-2024). The demonstration projects are described in D4.1 (Demonstration implementation plans).

Descriptive assessment

The term is used in D1.2 (Evaluation framework) to denote the process of quantitative or qualitative estimation of KPI values.

Do-nothing scenario

It is the equivalent of the baseline scenario for a demonstration action. It describes an imaginary situation where the specific demonstration action under examination does not materialise. It is used for defining the effects of the demonstration action.

Evaluation

The process of benchmarking alternative options based on a set of standards. In the framework of the present document, evaluation follows the assessment activity and aims at horizontal comparisons of the effectiveness of the demonstrated technologies and the investigation of the necessary preconditions that influence the project scalability and transferability.

Ex ante assessment

Also known as ‘project appraisal’ or ‘feasibility study.’ It denotes the assessment action that takes place before the planned intervention and aims at predicting the expected impact of the activities involved. If possible, two different ex ante assessments will be performed under WP1 of SOLUTIONSplus: those concerning the demonstration projects, and the revisited ones concerning the up-scaled projects.

Ex post assessment

It denotes the assessment action that takes place after the completion of the planned activities and aims at examining the impacts achieved. WP1 will perform the ex post assessment of the demonstration projects with the aim of obtaining the information needed for the ex ante assessment of the up-scaled projects.

Global scale

In developing the scale for a particular KPI, a global scale is constructed by assigning the minimum (1 star) and maximum (5 stars) points of the scale to the KPI value of the best and the worst conceivable performances. Unlike the local one, a global scale is not constrained by the set of alternatives under examination.

Impact

Impact can be conceptualized as the longer-term effects of a project within pre-determined boundaries. It is usually broader that outcome in terms of reach, scope, and nature. In the context of the present document, the term is associated with the expected effects of the up-scaled projects.

Impact assessment

The process of collecting and analysing quantitative and qualitative data for the purpose of improving the performance of the system under examination. The economic, social, and environmental effects of the SOLUTIONSplus up-scaled projects will be assessed through a set of KPIs.

Internal rate of return (IRR)

It denotes the rate of return that sets the net present value of the future cash flows of a project equal to zero. An IRR higher than the opportunity cost of the project owner indicates a profitability that exceeds the expected one from other activities and suggests the undertaking of the project. The higher a project’s IRR is, the more desirable its undertaking becomes.

Key performance indicator (KPI)

In MCDA the term ‘key performance indicator’ (KPI) denotes the metric used for estimating a specific attribute. In the frame of this report, however, KPIs refer to impact assessment criteria in the same way that ‘attributes’ do. A subtle difference exists only in the specific context of attribute scoring (note the difference between ‘KPI value’ and ‘attribute value’) and only for certain attributes.

KPI star value

Also known as ‘score,’ the KPI star value is the KPI value expressed in a 5-point star scale.

The transformation is performed through the value functions. If, for example, the agreed value function looks like the following schedule 1 star: $\Delta \geq 15\%$; 2 stars: $5\% < \Delta < 15\%$; 3 stars: $-5\% \leq \Delta \leq 5\%$; 4 stars: $-15\% < \Delta < -5\%$; and 5 stars: $\Delta \leq -15\%$, then a KPI value of -200 accidents corresponds to a reduction of 10% (in comparison to the baseline scenario) and 4 stars.

KPI value

Defined as the difference between the attribute value of a specific up-scaled project design in the target year and the corresponding attribute value under the baseline scenario. To refer to the example mentioned under 'attribute value,' if the number of major accidents in 2030 under the baseline scenario is expected to be 2,000 per year, then the KPI value is -200 (=1,800-2,000). Note that the above definition does not apply in cases of attributes defined as a differential to the baseline scenario. In those cases, the KPI value is identical to the corresponding attribute value.

Local scale

In developing the scale for a particular KPI, the local scale is constructed by assigning the minimum point (1 star) to the KPI value of the least performing alternative under examination, while the maximum point (5 stars) is given to the KPI value of the best performing alternative. In contrast to a global scale, the local one is defined only by the set of alternatives under examination.

Net present value (NPV)

Reflecting the present worth of an investment, NPV is defined as the sum of all future cash flows discounted at a periodic rate of return to account for the time value of money. A positive NPV indicates that the projected earnings generated by the project exceeds the anticipated costs and the project can be accepted.

On-going assessment

Also called 'monitoring,' it denotes the action that takes place during the implementation phase of an intervention and aims at tracking progress towards reaching the desired output and outcome. No formal on-going assessment will be performed for the SOLUTIONSplus demonstration actions due to their short duration.

Outcome

Outcome describes the immediate benefits that a project is designed to deliver. It differs from output in the sense that outcome goes beyond the mere deliverables of a project to define its immediate short-term effects.

Output

The output of a project describes the quality, quantity, and timeliness of the deliverables of the project at the time of conclusion. Thus, it includes all products, services, or other results (e.g. reports, papers, etc.) that a project generates.

Payback period

It denotes the time (in years) required to recover the funds expended in an investment or to reach the break-even point. It does not consider the time value of money, a fact that makes it easy to apply and understand. Useful when comparing similar investments.

Project component

Constituent of the demonstration project that behaves as a separate system independently of other parts of the transportation system. Although interactions with other components may exist, each component can function autonomously. Its assessment is performed separately.

Relative weights

Relative weights indicate stakeholder priorities within a family and sum to 1. For example, in the Kathmandu demo, the relative weights in the road safety family are: 0.421 for major accidents, 0.288 for minor accidents, and 0.291 for accidents involving VRUs (refer to Figure 4 in Vol. 4).

Sensitivity analysis

Determines how different values of an independent variable affect a particular dependent variable under a given set of assumptions. The method investigates how various sources of uncertainty in an assessment contribute to the overall uncertainty of its results. In other words, it is used to test the robustness of the assessment results.

Swing weighting

It is the suggested weighting method, as it considers the scaling effects of the alternatives in addition to their relative importance. In swing weighting the relative importance is determined based on moving from the worst to the best score on the relevant scales (full swing).

Target year

Denotes the end of the period examined by an assessment and determines the final year for which potential project impacts are assessed. For the needs of SOLUTIONSplus, 2030 has been selected as the target year to align with the target setting of the authorities in the demonstration cities of the project.

Up-scaled project

The integrated electric urban mobility project that will result from the SOLUTIONSplus actions in each demonstration city. It will be designed together with the local stakeholders based on the demonstration results. This up-scaled project constitutes the ultimate goal of each city demonstration and will be implemented after the completion of SOLUTIONSplus.

Value function

It is used for transforming a KPI value to its star equivalent. It can be quantitative in nature if the KPI value is measurable, or qualitative if both the end and intermediate points of the scale are defined verbally. When even the qualitative scale is infeasible, decision makers have the option of positioning the alternatives directly on the 5-star scale (direct rating).

Appendix B. KPI definitions

B1. Financial indicators

B1.1. Financial viability

Financial viability can be assessed through several indicators depending on the type of project examined (profit maximizing or cost minimizing operation) and the intended use.

Profit maximising projects

Commercial applications undertaken by private operators are usually profit maximizing projects. In these cases, both revenues and out-of-pocket costs need to be estimated for the entire life duration of the project. The indicators used for such cases are the Net Present Value (NPV), Internal Rate of Return (IRR) and the Payback Period. The first two are considered more formal and are usually required by the financing institutions. Payback period is the most popular one among non-economists, as it is the easiest indicator to comprehend.

NPV (Net Present Value)

Reflecting the present worth of an investment, NPV is defined as the sum of all future cash flows discounted at a periodic rate of return to account for the time value of money. A positive NPV indicates that the projected earnings generated by the project exceeds the anticipated costs and the project can be accepted. The NPV of the up-scaled project will be calculated via a specialized software, including the UNEP e-MOB, which offers this possibility. A value function will be needed to transform the NPV (expressed in monetary terms) into a star value as required by the evaluation framework.

IRR (Internal Rate of Return)

IRR denotes the rate of return that sets the net present value of the future cash flows of a project equal to zero. An IRR higher than the opportunity cost of the project owner indicates a profitability that exceeds the expected one from other activities and suggests the undertaking of the project. The higher a project's IRR is, the more desirable its undertaking becomes. The IRR of the up-scaled project will be calculated via a specialized software. A value function will be needed to transform the IRR (expressed in %) into a star value as required by the evaluation framework.

Payback period

It denotes the time (in years) required to recover the funds expended in an investment or to reach the break-even point. It does not consider the time value of money, a fact that makes it easy to apply and understand. The lower a project's payback period is, the more desirable its undertaking becomes. The payback period of the up-scaled project will be calculated via a specialized software. A value function will be needed to transform the payback period (expressed in years) into a star value as required by the evaluation framework.

Cost minimising projects

There are projects, mainly in the public sector, where revenues either do not exist or are very difficult to monetize. The Cost Effectiveness Ratio (CER) is the appropriate indicator for such cases.

CER (Cost Effectiveness Ratio)

CER relates the costs of a project to its key outcomes. The method identifies the costs of the project and ascribes monetary values to them. It then identifies the primary outcome of the project and quantifies it in terms of 'units of effectiveness' (e.g., number of lives saved, volume of waste collected, etc.). CER is obtained by dividing total costs by the units of effectiveness. The lower a project's CER is, the more desirable its undertaking becomes. A value function will be needed to transform the CER (expressed as a percentage difference from the CER of the baseline solution) into a star value as required by the evaluation framework.

B1.2. Availability of financial resources

This KPI complements the ones on financial viability and plays an important role in occasions where the up-scaled project is not sustainable financially but still generates social benefits exceeding its social costs.

Question	**Are the necessary external funds for implementing the project available?** Indicate your views by selecting one of the ratings defined in the 'Evaluation box' below:
Procedure	Evaluation by project experts followed by validation by local stakeholders
Notes	The evaluation combines your assessment on three separate dimensions: A. The availability of government/regional/city funds for supporting the project B. The intention of international donors to get involved in funding e-mobility projects of the suggested nature C. The preparedness of commercial banks to support projects concerning e-mobility in the project city through preferential interest rates or other incentives
Evaluation	1. The answer to all three dimensions (A and B and C) is negative 2. The answer to either A or B is positive, while C is negative 3. The answer to both A and B is positive, while C is negative 4. The answer to both A and B is negative, while C is positive 5. The answer to C and one or both of A and B is positive

A 5-point scale is used for scoring. The score directly enters the evaluation framework.

B2. Institutional/political indicators

B2.1. Coherence with national plans and development goals

Question	**How does the scaled-up project align with national or city level plans and policies?** Indicate your views by selecting one of the ratings defined in the 'Evaluation box' below:
Procedure	Evaluation by project experts followed by validation by local stakeholders
Notes	The evaluation combines your assessment on four separate policy categories: A. Alignment with **transport policy** at national or city level (e.g., National Transport Plan, City Master Plans, etc.) B. Alignment with **energy policy** at national level (e.g., Energy Performance / Efficiency Standards, etc.) C. Alignment with **environmental policy** at national or city level (e.g., emission standards, waste, and recycling policies, etc.) D. Alignment with **overarching policies** at national level (e.g., National Development Plans, Climate Action Plans, NDCs, etc.)
Evaluation	1. The alignment with categories A, B, C and D is negative 2. The alignment with one of the four categories A, B, C and D is positive but

	negative with remaining three dimensions 3. The alignment is positive with any two categories (category A, B, C & D) 4. The alignment is positive with any three categories (category A, B, C & D) 5. The alignment is positive with all categories (category A, B, C & D)

A 5-point scale is used for scoring. The score directly enters the evaluation framework.

B2.2. Alignment with supra-national/national/city legislation & regulations

This KPI intends to capture the alignment or compliance of the proposed project and its components with relevant legislation and regulations. As seen below, it is ideal that the process is embedded into local discussions, and consultations with experts.

Question: **What is the level of compliance of the project to the applicable regulations and laws?**

Procedure: The assessment entails the following steps:

1. Identification of relevant regulations that would need to be complied with by the (up-scaled) project concept and its components based on the categories below (list down all relevant/applicable regulations as identified during the consultation meetings and conversations with experts/suppliers/authorities). Please note that the identification of such would entail a multi-scalar approach, as there might be supra-national, national, sub-national, and local regulations that might apply to the project and its elements.

   - **Vehicle standards and regulations** – including applicable homologation regulations (if applicable)
   - **Charging equipment and infrastructure** – including relevant standards for charging equipment and infrastructure
   - **Business regulations** – would encompass regulations applicable to the set-up and the process of providing the services (e.g. competition regulations; regulations pertaining to the legal requirements for emergent business models)
   - **Traffic regulations** – e.g. eligibility of the project vehicles to operate in the proposed area/ types of roads
   - **Charging operations** – e.g. regulations pertaining to the operations/provision of charging services
   - **User / consumer protection regulations** – e.g. for shared schemes – data protection, fair pricing regulations
   - **Environmental regulations** – e.g. end-of-life regulations (battery recycling, etc.).

2. The alignment/compliance of the project concept to the identified regulations and laws will be assessed based on the following levels of compliance:

   - **Full compliance:** It can be ascertained that the relevant project element/s is/are fully compliant with the regulation.
   - **Presence of uncertainty:** Situations wherein it cannot be fully ascertained whether the relevant element/s of the proposed project is/are either fully compliant to, or appropriately covered by existing regulations, or in cases where potential significant regulatory hurdles are foreseen (e.g. impending changes in regulations).

- **Non-compliance:** It can be ascertained that the relevant project element/s would not comply with the applicable regulation/s.

3. Assign a score to the project concept based on the 5-point scale provided below:

	Description
1	It is certain that the proposed project would **not comply** with at least 1 applicable regulation
2	There have been identified **at least 3 instances of uncertainties** in relation to the compliance of the proposed project with the applicable regulations
3	There have been identified **2 instances of uncertainties** in relation to the compliance of the proposed project with the applicable regulations
4	There has been identified **1 instance of uncertainty** in relation to the compliance of the proposed project with the applicable regulations
5	The proposed project **complies** with all applicable regulations identified above

The score directly enters the evaluation framework.

B2.3. Ease of implementation (in terms of administrative barriers)

Question	**How easy it is to implement the project from an institutional/political point of view?** Indicate your views by selecting one of the ratings defined in the 'Evaluation box' below:
Procedure	Evaluation by project experts followed by validation by local stakeholders
Notes	The evaluation combines your assessment on three separate dimensions: A. The project requires administrative interventions of limited scope from the relevant political and institutional bodies, e.g. activities for passing a new law that will make the uptake of an e-mobility solution possible B. The political and institutional bodies needed for supporting the implementation of the project are in place C. The existing national/city political and institutional bodies are (likely to be) supportive of the necessary actions required for the project implementation
Evaluation	1. The answer to all three dimensions (A and B and C) is negative 2. The answer to either A or B is positive, while C is negative 3. The answer to both A and B is positive, while C is negative 4. The answer to both A and B is negative, while C is positive 5. The answer to C and one or both of A and B is positive

A 5-point scale is used for scoring. The score directly enters the evaluation framework.

B3. Climate-related indicators

B3.1. Effect on GHG emissions

This KPI is defined as the percentage change in the absolute mass of GHG emissions resulting from the new e-mobility solution under consideration in comparison to the baseline scenario (defined by the type of services/vehicles relevant to the scaled-up project components). In line with the e-MOB definition, it concerns **well-to-wheel CO_2 emissions** accumulated over the entire assessment period (2024 to 2030). Although the use of the e-MOB model is advisable for compatibility purposes, other calculators can be used if necessary. A value function will be needed to transform the percentage change of CO_2 emissions into a star value as required by the evaluation framework.

B4. Environmental indicators

B4.1. Effect on air pollutants

NOx emissions abated

This KPI is defined as the percentage change in the absolute mass of NOx emissions resulting from the new e-mobility solution under consideration in comparison to the baseline scenario (defined by the type of services/vehicles relevant to the scaled-up project components). In line with the e-MOB definition, it concerns **tank-to-wheel NOx emissions** accumulated over the entire assessment period (2024 to 2030). Although the use of the e-MOB model is advisable for compatibility purposes, other calculators can be used if necessary. A value function will be needed to transform the percentage change of NOx emissions into a star value as required by the evaluation framework.

$PM_{2.5}$ emissions abated

This KPI is defined as the percentage change in the absolute mass of $PM_{2.5}$ emissions resulting from the new e-mobility solution under consideration in comparison to the baseline scenario (defined by the type of services/vehicles relevant to the scaled-up project components). In line with the e-MOB definition, it concerns **tank-to-wheel $PM_{2.5}$ emissions** accumulated over the entire assessment period (2024 to 2030). Although the use of the e-MOB model is advisable for compatibility purposes, other calculators can be used if necessary. A value function will be needed to transform the percentage change of $PM_{2.5}$ emissions into a star value as required by the evaluation framework.

B4.2. Effect on noise

Noise exposure does not only depend on its magnitude, but also of its intensity, frequency, duration, variability, and time of occurrence. It is therefore advised to measure the subjective perception of the respondent in question (using categorical scales: e.g., noisy vs. quiet, annoying vs. not annoying, disagreeable vs. agreeable). Nevertheless, this perception should additionally be related/validated with acoustic measures (e.g., average day (LrD) and nighttime (LrN) road traffic noise levels in dB or dB(A)).

The proposed evaluation scheme focuses on the noise performance of the specific type of EV introduced (NEW) in comparison to the baseline solution (OLD), which must be defined a priori. It consists of two equally weighted parts; a subjective one (marked as Evaluation 1.1) and an objective one (marked as Evaluation 1.2). Evaluation 1.1 reflects the perceptions of the users/drivers of the EVs, while Evaluation 1.2 is based on average noise measurements inside the vehicle. A 5-point scale is used for both parts and the final score is the arithmetic mean of the two partial scores. The final score directly enters the evaluation framework. No value function is required for this evaluation scheme. However, the relative weights of the two parts (50/50) and the numerical values determining the scoring scale need to be validated by the local stakeholders.

Question	What is the project's impact on road noise exposure?				
Evaluation 1.1* (subjective) Perceived road noise exposure (user/driver)	1 Significantly noisier	2 Slightly noisier	3 No difference	4 Slightly quieter	5 Significantly quieter
Evaluation 1.2* (objective) Changes in average noise levels in dB(A) (NEW vs. OLD)	> +2.5 dB(A)	Up to +2.5 dB(A)	+/- 0.5 dB(A)	Up to -2.5 dB(A)	< -2.5 dB(A)

*Perceived road noise exposure and average noise levels are surveyed/measured inside/on the vehicle. This "frog perspective" gives us autarkic results that do not depend on the level of implementation (i.e., demo vs. up-scaled solution).

B4.3. Effect on environmental resources

Circular Economy (CE) is defined as "an economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling, and recovering materials in production/distribution and consumption processes. It operates at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, thus simultaneously creating environmental quality, economic prosperity, and social equity, to the benefit of current and future generations". The CE is based on three shared principles, which can be summarized as follows: (i) design out waste and pollution, (ii) keep products and materials in use, and (iii) regenerate natural systems[10].

Question	**Does the project enhance/promote circular economy in the project city**? Indicate your views by selecting one of the ratings defined in the 'Evaluation box' below:
Procedure	Evaluation by project experts followed by validation by local stakeholders
Notes	The evaluation combines your assessment on three separate dimensions: A. Useful application of materials through: • **recycling** – i.e., processing materials to obtain the same (high grade) or lower (low grade) quality, and/or • **recovering** – i.e., incineration of material with energy recovery B. Smarter vehicle uses and manufacturing through: • **rethinking** – i.e., making vehicle use more intensive (e.g., by sharing arrangements), and/or • **reducing** – i.e., increasing efficiency in vehicle manufacturing or use by consuming fewer natural resources and materials

[10] Saidani, M., Yannou, B., Leroy, Y., Cluzel, F., Kendall, A. (2019). A taxonomy of circular economy indicators. Journal of Cleaner Production, Volume 207, pp. 542-559.

	C. Expanded lifespan of vehicles and their parts through: • **reusing** – i.e., using of a discarded vehicle that is still in good condition and fulfils its original function by another operator/user, and/or • **repairing** – i.e., maintaining/repairing defective parts so that the vehicle can be used with its original function, and/or • **remanufacturing** – i.e., using parts of discarded products in a new vehicle with the same or different function
Evaluation	1. The answer to all three dimensions (A and B and C) is negative 2. The only positive answer concerns dimension A 3. The only positive answer concerns dimension B 4. The only positive answer concerns dimension C or the answer to C is negative but both A and B receive positive answers 5. The answer to C and one or both of A and B is positive

A 5-point scale is used for scoring. The score directly enters the evaluation framework.

B5. Social indicators

B5.1. Effect on accessibility

Access to jobs, opportunities, and services (personal travel)

The indicator assesses the impact of the e-mobility solutions on accessibility. The SDG 11.2 indicator will be used for this purpose. It is defined as the proportion of the population that has convenient access to public transport (by sex, age, and persons with disabilities). The KPI value will be estimated as the difference in the SDG 11.2 indicator values with and without the proposed scaled-up project. The SDG 11.2 indicator values will be calculated with support from DLR, using openly available data on population and street network. The DLR open-source tool *UrMoAc* will be used for calculating the accessibility values.[11]

Remark: If there are no further stops added in a city, there will be no impact on this indicator. Solutions such as e-bikes will be considered to increase accessibility through rental stations. Same holds for 3-wheelers & motorbikes.

Required data inputs

- Population distribution in the city (Source: DLR World Settlement Footprint)
- Street network for walking (OSM-OpenStreetMap)
- Public transit stops (locations, ideally including different entrances)

Every city has one percentage value describing the current state of reaching the indicator goal.

[11] GitHub - DLR-VF/UrMoAC: A tool for computing accessibility measures, supporting aggregation, variable limits, and intermodality.

City	SDG 11.2 value, official value from UN Habitat[12]	SDG 11.2 value, SOL+ Scenario	Difference
Hanoi	n/a		
Pasig	n/a		
Kathmandu	n/a		
Dar es Salaam	n/a		
Kigali	50.33 %		
Quito	88.53%		
Montevideo	n/a		
Hamburg	90.5%	91.5% (example)	+1% (example)
Madrid	98.44%		

A value function will be needed to transform the KPI value obtained in the way described above into a star value as required by the evaluation framework.

Access to pick-up/delivery locations (freight)

In cities where the implemented e-mobility solutions also affect goods transport and freight, a qualitative judgement including experts from the field (min: n = 10) will be carried out. This judgement will mainly reflect the perspective of the users of the new e-cargo solutions (e.g., parcel delivery services) and will focus on aspects concerning the pick-up/delivery operations (e.g., parking possibilities, time restrictions, etc.). The views of other impacted stakeholders (e.g., shopkeepers, pedestrians, etc.) can also contribute to the assessment.

Question	**What is the impact of the e-mobility solutions on improving the pick-up/delivery operations of freight and goods transport?**				
Qualitative judgement by experts	1 Degradation	2 Slight decline	3 No difference	4 Slight improvement	5 Major improvement

A 5-point scale is used for scoring. The score directly enters the evaluation framework.

B5.2. Affordability of e-mobility services

Question: **What is the expected change in the average price of the e-mobility services that the potential target users must pay?**

Proposed unit: Percentage change in price per passenger-kilometre (%ΔP/pkm) or price per ton-kilometre (%ΔP/tkm).[13] The prices are to be quoted in local currencies.

[12] Available Online, last accessed: May 19th, 2021: https://data.unhabitat.org/datasets/11-2-1-percentage-access-to-public-transport/

[13] Essentially, one can think of this in terms of price paid by the intended user per unit of transportation activity, on average. For example, a user of an e-bike sharing scheme would pay #EUR per pkm. If they will not use the e-bike sharing system, they would have used a motorcycle, which would cost #EUR per pkm. The % difference would be accounted for.

Description:

This KPI intends to capture the potential impact of the proposed project concept in terms of the costs to the targeted users against the baseline scenario wherein the proposed project will not take place. It is important to ask "what would the users utilise (e.g. in terms of modes, or vehicles) in conducting the same transportation activity (either passenger or goods transport, depending on the project concept) if the project is not put in place. The baseline average costs can be based on different options such as: the most dominant existing alternative or mix of alternatives based on surveys of users;[14] or based on the modal characteristics of a "typical route" in a city. The selection of the approach would vary depending on the project design, its boundaries, as well as resources for gathering data. This depends on the availability of data, and the applicability of the options to the specific project concept.[15]

Procedure:

1. Define the boundaries of the analysis (i.e., select the part of the network or a 'typical route' that will be examined)
2. Determine the average price/pkm or price/tkm of e-mobility service/s to be provided to the targeted users within the selected boundaries under the proposed project.
3. Determine the average price/pkm or price/tkm for the baseline scenario. The baseline price can be based on the average price/pkm or price/tkm for the mode that would most likely be used in the absence of the project.
4. Calculate the percentage difference between the average prices of Steps 2 & 3.

A value function will be needed to transform the KPI value obtained in the way described above into a star value as required by the evaluation framework.

B5.3. Effect on travel time

Change in travel times due to e-mobility services (personal travel)

Proposed unit: **Percentage change in average travel time (expressed in minutes) between the up-scaled and baseline scenarios calculated on a predefined 'typical route' in the city**

Procedure:

1. Define the 'typical route' or the boundaries of the analysis
2. Define the transport solution that would be used under the baseline scenario for the same transport defined in Step 1 (it can be the dominant alternative or a mix of alternatives as explained in Section B5.2)
3. Measure total travel time on the predefined route under the baseline scenario [min]. To improve accuracy, the estimate can be the arithmetic mean of multiple measurements on the same route by the same modes/vehicles

---

[14] In case detailed user surveys are to be conducted in the demo phase, it is highly recommended that users be asked a question such as "what mode would you normally use in conducting this trip (i.e. if they had just used an e-mobility service provided by the demo)"? Average costs per pkm or tkm can be computed based on the % shares.

[15] The average cost calculation should also consider the appropriate fee structures based on the local context (e.g. progressive fee structures based on distance, fixed + variable costs, etc…). Average trip lengths can be used as a basis for calculating the average costs and comparing them (e.g., how much a 5 km trip would cost in the project scenario and the base scenario).

4. Measure the travel time and calculate the travel time per vehicle kilometre for the new e-mobility solution assessed during the demonstration activities in the city [min/v-km]
5. Use the travel time per transport mode [min/v-km] of Step 4 to calculate the travel time for the predetermined route in the up-scaled scenario [min]
6. Calculate the percentage difference in travel time between the up-scaled and baseline scenarios

A value function will be needed to transform the KPI value obtained in the way described above into a star value as required by the evaluation framework.

Change in travel times due to e-mobility services (freight)

Proposed unit: **Percentage change in average travel time for freight transport (expressed in minutes) between the up-scaled and baseline scenarios calculated on a predefined 'typical route' in the city**

Procedure:

1. Define the 'typical route' or the boundaries of the analysis
2. Define the transport solution that would be used under the baseline scenario for the same transport defined in Step 1 (it can be the dominant alternative or a mix of alternatives as explained in Section B5.2)
3. Measure total travel time for freight transport on the predefined route under the baseline scenario [min]. To improve accuracy, the estimate can be the arithmetic mean of multiple measurements on the same route by the same modes/vehicles
4. Measure the travel time and calculate the travel time per vehicle kilometre for the new freight transport e-mobility solution assessed during the demonstration activities in the city [min/v-km]
5. Use the travel time per freight transport mode [min/v-km] of Step 4 to calculate the travel time for the predetermined route in the up-scaled scenario [min]
6. Calculate the percentage difference in freight travel time between the up-scaled and baseline scenarios

A value function will be needed to transform the KPI value obtained in the way described above into a star value as required by the evaluation framework.

B5.4. Effect on road safety

The impact on road safety will be assessed in terms of changes in accident frequency and severity. Preferably, data will be collected in the area where the demo(s) are implemented or at the city level. Two different approaches of increasing complexity will be used for road safety assessment. The first and simpler one is based on the three safety-related KPIs that enter the evaluation framework. Their definition and estimation methods will be presented in the three subsequent headings in line with the other indicators of the evaluation framework. The second approach is a more elaborate one and comprises the descriptive evaluation. Two additional indicators are used for this purpose. Their definition and estimation is presented in Section E.4.4 below.

Road accidents with fatalities/serious injuries

Definition: **Annual number of accidents where someone was killed or seriously injured as a result of a road accident involving motor vehicle(s)**

Question	**Please estimate the potential impact of the proposed up-scaled project in terms of <u>number of road accidents with fatalities/serious injuries</u> in the area (compared to the situation before the implementation)** Indicate your views by selecting one of the ratings defined in the 'Evaluation box' below:
Procedure	The target audience consists of professional groups such as road safety experts (e.g., from road safety authorities or from cities/municipalities), people involved in emergency operations (e.g., ambulance drivers, medical staff), experts on traffic operations from the city/municipality (e.g., police officers, traffic management, traffic planning), and other professionals responsible for the demo area services and/or operations related to road infrastructure
Evaluation	1. Significant negative effect on the road safety situation in the area/city (i.e., significant increase in number of road accidents with fatalities/serious injuries) 2. Negative effect on the road safety situation in the area/city (i.e., moderate increase in number of road accidents with fatalities/serious injuries) 3. Slight negative effect on road safety situation in the area/city (i.e., slight increase in number of road accidents with fatalities/serious injuries) 4. No change in road safety situation in the area/city 5. Slight positive effect on the road safety situation in the area/city (i.e., slight decrease in number of road accidents with fatalities/serious injuries) 6. Positive effect on the road safety situation in the area/city (i.e., moderate decrease in number of road accidents with fatalities/serious injuries) 7. Significant positive effect in the road safety situation in the area/city (i.e., significant decrease in number of road accidents with fatalities/serious injuries)

A 7-point scale is used for scoring. A value function will be needed to transform scores into the 5-point scale of the evaluation framework.

Road accidents with minor injuries/material damage

Definition: **Annual number of accidents involving persons who sustained a minor injury or resulted in property loss (e.g., vehicle damage) as a result of a road accident involving motor vehicle(s)**

Question	**Please estimate the potential impact of the proposed up-scaled project in terms of the <u>number of road accidents with minor injuries/material damage</u> in the area (compared to the situation before the implementation).** Indicate your views by selecting one of the ratings defined in the 'Evaluation box' below:
Procedure	The target audience consists of professional groups such as road safety experts (e.g., from road safety authorities or from cities/municipalities), people involved in emergency operations (e.g., ambulance drivers, medical staff), experts on traffic operations from the city/municipality (e.g., police officers, traffic management, traffic planning), and other professionals responsible for the demo area services and/or operations related to road infrastructure
Evaluation	1. Significant negative effect on the road safety situation in the area/city (i.e., significant increase in number of road accidents with minor injuries/material damage) 2. Negative effect on the road safety situation in the area/city (i.e., moderate increase in number of road accidents with minor injuries/material damage)

	3. Slight negative effect on road safety situation in the area/city (i.e., slight increase in number of road accidents with minor injuries/material damage) 4. No change in road safety situation in the area/city 5. Slight positive effect on the road safety situation in the area/city (i.e., slight decrease in number of road accidents with minor injuries/material damage) 6. Positive effect on the road safety situation in the area/city (i.e., moderate decrease in number of road accidents with minor injuries/material damage) 7. Significant positive effect in the road safety situation in the area/city (i.e., significant decrease in number of road accidents with minor injuries/material damage)

A 7-point scale is used for scoring. A value function will be needed to transform scores into the 5-point scale of the evaluation framework.

Road accidents involving vulnerable road users (VRUs)

Initially, the third safety related KPI of the evaluation framework concerned the frequency of traffic-related near accidents/dangerous situations. Although this is a subject that deserves due consideration, the lack of sufficient data lead to the decision of replacing it with another important issue, the safety of vulnerable road users (VRUs). Nevertheless, the frequency of traffic-related near accidents/dangerous situations remains a topic of interest and is considered in the descriptive evaluation of the following heading.

Definition: **Annual number of accidents involving any pedestrians, cyclists, or riders of powered-two-wheelers (or powered-three-wheelers when relevant), who were slightly or severely injured or killed as a result of a road accident involving motor vehicle(s) or not (occupants of vehicles may or may not be injured, but at least one VRU was injured/killed).**

Question	**Please estimate the potential impact of the proposed up-scaled project in terms of the number of road accidents involving VRUs in the area (compared to the situation before the implementation).** Indicate your views by selecting one of the ratings defined in the 'Evaluation box' below:
Procedure	The target audience consists of professional groups such as road safety experts (e.g., from road safety authorities or from cities/municipalities), people involved in emergency operations (e.g., ambulance drivers, medical staff), experts on traffic operations from the city/municipality (e.g., police officers, traffic management, traffic planning), and other professionals responsible for the demo area services and/or operations related to road infrastructure
Evaluation	1. Significant negative effect on the road safety situation in the area/city (i.e., significant increase in number of road accidents involving VRUs) 2. Negative effect on the road safety situation in the area/city (i.e., moderate increase in number of road accidents involving VRUs) 3. Slight negative effect on road safety situation in the area/city (i.e., slight increase in number of road accidents involving VRUs) 4. No change in road safety situation in the area/city 5. Slight positive effect on the road safety situation in the area/city (i.e., slight decrease in number of road accidents involving VRUs) 6. Positive effect on the road safety situation in the area/city (i.e., moderate decrease in number of road accidents involving VRUs) 7. Significant positive effect in the road safety situation in the area/city (i.e., significant decrease in number of road accidents involving VRUs)

A 7-point scale is used for scoring. A value function will be needed to transform scores into the 5-point scale of the evaluation framework.

Additional indicators entering the descriptive evaluation

The descriptive evaluation complements the safety assessment of the evaluation framework by gathering viewpoints on two additional indicators through professional groups and through registered users.

A. Traffic related near accidents/dangerous situations

Definition: **Annual number of traffic-related near accidents or dangerous situations. These are unplanned events that have the potential to cause a road accident, but the situation did not yet result in casualties or material damage.**

Question	**Please estimate the potential impact of the proposed up-scaled project in terms of the number of near accidents and dangerous situations in the area (compared to the situation before the implementation).** Indicate your views by selecting one of the ratings defined in the 'Evaluation box' below:
Procedure	The target audience consists of professional groups such as road safety experts (e.g., from road safety authorities or from cities/municipalities), people involved in emergency operations (e.g., ambulance drivers, medical staff), experts on traffic operations from the city/municipality (e.g., police officers, traffic management, traffic planning), and other professionals responsible for the demo area services and/or operations related to road infrastructure
Evaluation	1. Significant negative effect on the road safety situation in the area/city (i.e., significant increase in number of near accidents and dangerous situations) 2. Negative effect on the road safety situation in the area/city (i.e., moderate increase in number of near accidents and dangerous situations) 3. Slight negative effect on road safety situation in the area/city (i.e., slight increase in number of near accidents and dangerous situations) 4. No change in road safety situation in the area/city 5. Slight positive effect on the road safety situation in the area/city (i.e., slight decrease in number of near accidents and dangerous situations) 6. Positive effect on the road safety situation in the area/city (i.e., moderate decrease in number of near accidents and dangerous situations) 7. Significant positive effect in the road safety situation in the area/city (i.e., significant decrease in number of near accidents and dangerous situations)

No value function is required for this indicator as the score directly enters the descriptive evaluation.

B. Traffic-related near accidents/dangerous situations involving VRUs

Definition: **Annual number of traffic-related near accidents or dangerous situations involving VRUs, (VRUs & motor vehicle(s) or only VRUs). These are unplanned events that have the potential to cause a road accident, but the situation did not yet result in casualties or material damage.**

Question	**Please estimate the potential impact of the proposed up-scaled project in terms of the number of near accidents and dangerous situations involving VRUs in the area (compared to the situation before the implementation).**

	Indicate your views by selecting one of the ratings defined in the 'Evaluation box' below:
Procedure	The target audience consists of professional groups such as road safety experts (e.g., from road safety authorities or from cities/municipalities), people involved in emergency operations (e.g., ambulance drivers, medical staff), experts on traffic operations from the city/municipality (e.g., police officers, traffic management, traffic planning), and other professionals responsible for the demo area services and/or operations related to road infrastructure
Evaluation	1. Significant negative effect on the road safety situation in the area/city (i.e., significant increase in number of near accidents and dangerous situations involving VRUs) 2. Negative effect on the road safety situation in the area/city (i.e., moderate increase in number of near accidents and dangerous situations involving VRUs) 3. Slight negative effect on road safety situation in the area/city (i.e., slight increase in number of near accidents and dangerous situations involving VRUs) 4. No change in road safety situation in the area/city 5. Slight positive effect on the road safety situation in the area/city (i.e., slight decrease in number of near accidents and dangerous situations involving VRUs) 6. Positive effect on the road safety situation in the area/city (i.e., moderate decrease in number of near accidents and dangerous situations involving VRUs) 7. Significant positive effect in the road safety situation in the area/city (i.e., significant decrease in number of near accidents and dangerous situations involving VRUs)

No value function is required for this indicator as the score directly enters the descriptive evaluation.

Furthermore, coverage is expanded to include the perspective of registered users of the e-mobility solutions, preferably drivers of e-vehicles and/or riders of e-bikes or 3 wheelers. As such, the same **five questions** asked to a target audience of professional groups (those specified in the previous road safety headings) are also **posed to an audience of registered users** of e-mobility solutions. It is worth noting that considering the perspective of registered users herewith does not overlap with the road-safety related KPI on quality of services (Section B5.8, Feature #6), as the descriptive evaluation is not part of the attribute weighting structure.

Unlike the evaluation framework, which relies on the preferences and priorities of the local stakeholders that participate in the weighting of attributes and scoring of the alternative up-scaled projects, the descriptive evaluation integrates not only perspectives of professional groups but also registered users for the safety impact assessment, which is conducted by the city team. In fact, this approach, considering possible safety-related incidents observed during demonstration, is recommended for the ex-post assessment of the demonstration components.

B5.5. Effect on charging safety incidents

Ensuring charging safety is a key element in the pursuit of e-mobility solutions. Consideration towards the type of batteries and their charging technology/infrastructure to be utilised must be noted when assessing risks associated with battery operation and charging (i.e. conductive, inductive, battery swapping), as well as whether communication and charging coordination are featured in the system. The assessment should also take into consideration the mitigation measures and good practices that have already been embedded to address the risks.

The KPI on charging safety is hinged on the assessment of the risks (and essentially, the project's risk performance) relating to the following categories of hazards (adopted from Wang et al., 2019):[16]

- Electrical shock to users and personnel: Charging facilities can cause electrical hazards, which can include potential electrical shock to customers (if applicable to the design of the project), as well as electrical shock and arc flash hazards to workers. Here are some examples of instances, which can lead to electrical shock: potential failure of ground fault circuit-interrupting breaker, potential failure of charging circuit-interrupting devices due to environmental factors or due to vandalism activities like copper theft (Wang et a., 2019). Electric shock hazards greatly depend on the characteristics of the charger. Protection against electric shock can be achieved through basic protection (e.g. preventing persons from being in contact with the energized components or parts), and fault protection (protection in the event of failure of the basic insulation via disconnection of the supply). The reliability of the charging components with electrical safety protection features should be monitored and assessed through periodic safety inspections.
- Fire hazards: Fire hazards caused by charging of EVs may also affect personnel safety, as well as result in damage to property. Lithium-based batteries, for example, can self-ignite due to manufacturing errors, short-circuiting, exposure to extreme heat, or damage to the battery cell.[17] The pursuit of fast charging (and discharging) combined with the high driving performance of EVs is also documented to have a negative effect on fire risk (Sun et al., 2020). Fires due to charging may result from instances related to the following: overcharging, short circuiting, overheating of the charging environment, ignition of flammable materials, cable overload, faulty or insecure charging stations and cables, improper installation, improper charging practices, failure of the onboard charging equipment, and failure of the charging system in general. Protection against external forces that may result in fires should also be taken into consideration (e.g. arson, burning in the vicinity, among others).
- Power grid instability: The potential impacts of the high penetration of uncontrolled charging can result in negative impacts to the power system due to potentially significant increases in peak demand; voltage deviation from acceptable limits; phase unbalance due to single-phase chargers; harmonics distortion; overloading of power system equipment; increase of power losses (Habib et al., 2014). The main key variables are: penetration level (i.e. the amount of EVs to be introduced into the system); the EV battery charger (i.e. fast chargers expected to increase peak demand than slow chargers); time of charging (i.e. EVs charging at the same time; interference with the peak demand time); location; battery capacity (i.e. high capacity batteries will draw larger amounts of energy); battery state-of-charge; state of the distribution

[16] Hazards refer to potential sources that may cause harm. Risks relate to the combination of the probability of occurrence of harm and the severity of that harm.

[17] https://www.terrellhogan.com/electric-vehicle-battery-fire-risks/

system (e.g. structure, equipment loading conditions, voltage level, and profile, load profile, etc.) (Nour et al., 2020).

Procedure:
The assessment of this KPI requires that the analyst scores the three categories in terms of severity and probability of occurrence. Only experts with good technical knowledge are involved in the assessment. The guidance for scoring the potential scale/severity of impacts is provided in the table below:

	Potential Severity/Scale of Impact[18]
0	If no adverse impact expected
1	If minor adverse impact expected
2	If low adverse impact expected
3	If moderate adverse impact expected
4	If high adverse impact expected

For the designed charging system solution, the risk probability (likelihood of occurrence) is characterized as:

	Likelihood of Occurrence[19]
0	If the likelihood of occurrence is very low (less than once per 10 years)
1	If the likelihood of occurrence is low (less than once per 5 years)
2	If the likelihood of occurrence is moderate (once per year)
3	If the likelihood of occurrence is high (once per month)
4	If the likelihood of occurrence is very high (once per week or more frequently)

The scores for each of the hazard categories should be inputted in the tool as shown in the table below:

Hazards Categories	Impact (consequences)	Probability (likelihood)	Risk Score (Impact* Probability)
Electrical shock			
Fire hazards			
Power grid instability			

It is conceivable that the experts who will undertake the assessment of charging safety might select to include in the analysis a more detailed breakdown of hazards under each of the categories mentioned above. In this case, the hazard category in the above tool should be replaced by the corresponding set of constituent sub-hazards, each one of which will have to be assessed separately as all other hazards.

A value function will be needed to transform scores into the 5-point scale of the evaluation framework.

B5.6. Effect on security incidents

[18] Ideally to be assessed by local experts and should consider the scale (e.g. potential number of affected people) and severity of impacts.
[19] The assessment of the likelihood of occurrence should consider the safety measures that are embedded in the project.

Public transport security refers to measures taken by a transport system to keep its passengers, employees, and freight safe, to protect the operator's infrastructure and equipment, and to make sure that other violations do not occur. In order to identify and address potential security risks, this KPI applies the risk assessment methodology to four dimensions, herewith referred to as Security Performance Standard (PS):

- PS1: Infrastructure and operation
- PS2: Vehicles
- PS3: Transport of goods
- PS4: Transport of persons

Project concept / e-solution(s) risk assessment considers risk impact and risk probability as presented below.

The **risk impact** refers to the consequences/impact in case some unexpected security related event happens. The following scale is used:

	Risk impact
0	If no adverse impact expected
1	If minor adverse impact expected
2	If low adverse impact expected
3	If moderate adverse impact expected
4	If high adverse impact expected

For the designed e-mobility solution, the **risk probability** (likelihood of occurrence) is scored on the following scale:

	Risk probability
0	If the likelihood of occurrence is very low (less than once per 10 years)
1	If the likelihood of occurrence is low (less than once per 5 years)
2	If the likelihood of occurrence is moderate (once per year)
3	If the likelihood of occurrence is high (once per month)
4	If the likelihood of occurrence is very high (once per week or more frequently)

To assess the potential impacts of the proposed up-scaled project in terms of impact on security, the scores on risk impact and risk probability for every PS category are entered in the table below.

Security Performance Standard	Guiding aspect	Risk Impact (consequences)	Risk Probability (likelihood)	Security Performance Score
Instructions		*Choose from: No impact [0] to Very high impact [4]*	*Choose from: Very low probability [0] to Very high probability [4]*	*Risk Impact X Risk Probability*
PS1: Infrastructure and operation	*Infrastructure and operation security score*			
PS2: Vehicles	*Vehicles security score*			
PS3: Transport of goods	*Transport of goods security score*			
PS4: Transport of persons	*Transport of people security score*			

The perspectives of **all stakeholders** (e.g. operators, government, transport service providers) should be considered in the security risk assessment through meetings (online or local), workshops, or other events organized and facilitated by the city teams. End users (e.g., passengers of EVs) should be excluded, however, to avoid overlap with the personal security related KPI on quality of services (Section B5.8, Feature #7).

It is conceivable that the stakeholders participating in the security risk assessment might select to include in the analysis a more detailed breakdown of hazards under each of the PS categories mentioned above. In this case, the PS category in the above table should be replaced by the corresponding set of constituent sub-hazards, each one of which will have to be assessed separately as all other PS/hazards.

A value function will be needed to transform the difference in security performance scores between the new and old solutions into the 5-point scale of the evaluation framework.

B5.7. Effect on well-being due to active traveling

The basis for this KPI is the number of active kilometres associated with a specific up-scaled scenario. The active kilometres associated with the corresponding baseline solution are used for benchmarking. Since there exist different modes of active traveling, a homogenization process is required. The number of calories burned per kilometre of each transport mode is used for transforming active traveling distances into walking-equivalent kilometres, which serve as the homogenized unit. The conversion is based on the arithmetic mean of the calories burnt per kilometre by a 60kg 1,65m female and a 75kg 1,75m male person, as provided by the Activity Based Calorie Burn Calculator | SHAPESENSE.COM:

- Walking: 50.0 calories/km (based on 5km/h walking pace, 0% inclination)
- Cycling: 22.0 calories/km (based on 18km/h cycling pace)
- Driving scooter/motorcycle: 4.5 calories/km (based on 35km/h average speed)
- Driving car: 3.0 calories/km (based on 50km/h average speed)

The formula, then, for calculating active traveling activity (in walking-equivalent km) is:

*Active kilometres = kilometres walking + 22/50 * kilometres cycling + 4.5/50 * kilometres scooter/motorcycle + 3/50* kilometres car*

Procedure:

1. Define the 'typical route' or the boundaries of the analysis
2. Define the transport solution that would be used under the baseline scenario for the same transport defined in Step 1 (it can be the dominant alternative or a mix of alternatives as explained in Section B5.2)
3. Determine the number of kilometres per active transport mode for the baseline scenario
4. Calculate the total number of walking-equivalent kilometres for the baseline scenario using the formula provided above
5. Based on information collected during the demonstration actions, determine the number of kilometres per active transport associated with the up-scaled scenario
6. Calculate the total number of walking-equivalent kilometres for the up-scaled scenario using the formula provided above
7. Calculate the difference in walking-equivalent kilometres between the up-scaled and the baseline scenarios.

A value function will be needed to transform the active traveling activity calculated as described above into the 5-point scale of the evaluation framework.

B5.8. Quality of e-mobility services

Note	In this part of the questionnaire, we would like to have your opinion on how the suggested new e-mobility solution (indicated below as 'NEW') compares to the preferred one that you used before for the same transport (indicated below as 'OLD') in relation to the eight different quality features shown below. Before doing so, please indicate in the next box the OLD solution that you were using previously.
OLD solution	*Please briefly describe here the OLD solution (e.g. own car, diesel bus, safa tempo powered by gas, etc.)*
Procedure	Direct rating by end users through survey/questionnaire, except for Feature #3, which will be assessed on the basis of feedback received from professional drivers
Feature #1 Suitability for adverse weather conditions	1. The OLD solution is much better than the NEW one 2. The OLD solution is better than the NEW one 3. I don't see a difference between the two solutions in relation to this feature 4. The NEW solution is better than the OLD one 5. The NEW solution is much better than the OLD one
Feature #2 Comfort in travel	1. The OLD solution is much more comfortable than the NEW one 2. The OLD solution is more comfortable than the NEW one 3. I don't see a difference between the two solutions in relation to this feature 4. The NEW solution is more comfortable than the OLD one 5. The NEW solution is much more comfortable than the OLD one
Feature #3	1. The OLD solution is much easier to drive than the NEW one

Ease of driving (by professional drivers)	2. The OLD solution is easier to drive than the NEW one 3. I don't see a difference between the two solutions in relation to this feature 4. The NEW solution is easier to drive than the OLD one 5. The NEW solution is much easier to drive than the OLD one
Feature #4 Ease of driving (by other users)	1. The OLD solution is much easier to drive than the NEW one 2. The OLD solution is easier to drive than the NEW one 3. I don't see a difference between the two solutions in relation to this feature 4. The NEW solution is easier to drive than the OLD one 5. The NEW solution is much easier to drive than the OLD one
Feature #5 Ease of charging/refuelling	1. The OLD solution is much easier to charge/refuel than the NEW one 2. The OLD solution is easier to charge/refuel than the NEW one 3. I don't see a difference between the two solutions in relation to this feature 4. The NEW solution is easier to charge/refuel than the OLD one 5. The NEW solution is much easier to charge/refuel than the OLD one
Feature #6 Safety	1. The OLD solution is much safer than the NEW one 2. The OLD solution is safer than the NEW one 3. I don't see a difference between the two solutions in relation to this feature 4. The NEW solution is safer than the OLD one 5. The NEW solution is much safer than the OLD one
Feature #7 Personal security (in terms of unlawful behaviours)	1. The OLD solution is much more secure than the NEW one 2. The OLD solution is more secure than the NEW one 3. I don't see a difference between the two solutions in relation to this feature 4. The NEW solution is more secure than the OLD one 5. The NEW solution is much more secure than the OLD one
Feature #8 Continuity of journey chains, including transshipment to other modes	1. The OLD solution is much better than the NEW one 2. The OLD solution is better than the NEW one 3. I don't see a difference between the two solutions in relation to this feature 4. The NEW solution is better than the OLD one 5. The NEW solution is much better than the OLD one

A 5-point scale is used for scoring all features. These scores will directly enter the evaluation framework.

B6. Wider economic indicators

B6.1. Effect on national/local budget

In public transport (e.g., buses) costs are often borne by the government. Therefore, any costs (capital and operational) higher than current expenditures put an additional burden on the government finances. To the contrary, a positive impact on budget is expected in the case of lower than current expenditures on public transport. Public investments are also needed for the provision of charging infrastructures, and these can put an additional burden on public finances.

Proposed unit: **Percentage change in the relevant public (national/local) budget due to the up-scaled project**

Procedure:

1. Define the baseline scenario to be used for benchmarking purposes
2. Calculate the annual public budget flows (expenditures and revenues) associated with the up-scaled project over its life. The e-MOB model or another specialized software can be used for this purpose.
3. Calculate the annual public budget flows (expenditures and revenues) associated with the baseline scenario over the same period.
4. Calculate the annual differences in budget flows and the average net annual flow. For cities that can use the UNEP e-MOB calculator, this figure can be obtained as the difference in the annual total cost of ownership between the up-scaled and baseline scenarios
5. Express the net annual flow as a percentage of the average public (national/local) budget calculated over the last three years (2019-2021).

The assessment should be performed by experts using information on capital expenditures and operating expenses over the project period. The results should be validated by local teams/stakeholders.

A value function will be needed to transform the percentage change in public budget as calculated above into the 5-point scale of the evaluation framework.

B6.2. Effect on external trade

Fossil fuel imports abated

Electric vehicles are expected to reduce demand for fossil fuels, which is of particular importance given that all countries within the project are net importers of oil. Therefore, any reduction in demand would reduce fossil fuel imports at the margin.

Proposed unit: **Percentage change in fossil fuel imports**

Procedure:

1. Define the baseline scenario to be used for benchmarking purposes
2. Calculate the vehicle-kilometres (vkm) for all modes using fossil fuels within the baseline scenario over project duration. The e-MOB model or another specialized software can be used for this purpose
3. Transform the baseline vkm to equivalent fuel consumption through the average energy intensity (litres of fuel per vkm) of each vehicle type in the fleet
4. Calculate the vehicle-kilometres (vkm) for all modes using fossil fuels within the up-scaled project over the same period. Use the same calculator as in Step 2
5. Transform the up-scaled project vkm to equivalent fuel consumption through the average energy intensity (litres of fuel per vkm) of each vehicle type in the fleet including those introduced by the project
6. Calculate the difference between the two estimates and express it as a percentage of the baseline fuel demand. For cities that can use the UNEP e-MOB calculator, the

difference between the up-scaled and baseline scenarios is calculated directly by the model

The assessment should be performed by experts using information on vehicle kilometres for different modes. The results should be validated by local teams/stakeholders.

A value function will be needed to transform the percentage change in fossil fuel imports as calculated above into the 5-point scale of the evaluation framework. It is worth noting that in this case the proposed unit of the KPI (%) masks the effect of the project on the absolute import value, which can be very important in specific economic environments. The local stakeholders should consider this aspect when defining the value function.

Other imports affected

Electric vehicles are expected to substitute for ICE vehicles in some cases (e.g., replacing a diesel bus with electric bus) and in other cases they are simply added to the fleet (e.g., e-scooters for last mile). The overall impact on imports can be negative or positive depending on the nature of the project and the baseline scenario used for benchmarking. Note that fuel imports are excluded from this analysis as they are dealt with above.

Proposed unit: **Change in imports of vehicles/parts**

Procedure:

1. Define the baseline scenario to be used for benchmarking purposes
2. Calculate the number of EVs to be introduced into the system due to the up-scaled project by type of vehicle
3. Estimate the value of the corresponding imports also accounting for the required maintenance during the useful life of the vehicles. The estimate should pay attention and exclude all inputs in products/services provided by local suppliers
4. Calculate the number and type of vehicles (EVs or ICE ones) that would have been used under the baseline scenario to provide the transport services foreseen by the up-scaled project
5. Estimate the corresponding value of imports as in Step 3
6. Calculate the difference between the two estimates

The assessment should be performed by experts using market information on various vehicle types. The results should be validated by local teams/stakeholders.

A value function will be needed to transform the change in import value as calculated above into the 5-point scale of the evaluation framework.

B6.3. Effect on employment

Job creation

This KPI is defined as the absolute number of net additional jobs (N_{NET}) expected to be generated by the assessed new e-mobility solution in comparison to the baseline scenario. N_{NET} is calculated as the difference between the jobs expected to be added (N_{ADD}) due to the new solution over the assessment period (2019 to 2030) and those expected to be lost (N_{LOST}) during the same period ($N_{NET} = N_{ADD} – N_{LOST}$). It is expected that the calculation will be based on the number of EVs entering the market and the estimated effects on the labour market as experienced through past projects in the demo city or elsewhere in the world. A value function will be needed to transform the number of additional jobs into a star value as required by the evaluation framework.

Technical skills requirements

Originally, this KPI was designed to capture possible effects on the wages in the urban transport sector and related occupations. However, after consultation with stakeholders, it was decided instead to approach this topic through the requirements on technical skills that the up-scaled project imposes. It is expected that these requirements will be reflected in the wages anyway.

According to the literature, the specialties relating to EVs concern: (i) EV technicians involved in the construction and mainly maintenance of the vehicles, (ii) EV design engineers involved in the design or remodelling of vehicles, and (iii) IT analysts or other Industry 4.0 experts involved in developing and maintaining transport related software applications (e.g., MaaS apps).

As in Section B5.7, a homogenization process is required. The average monthly salaries of these specialties in Switzerland, as provided by https://www.paylab.com/ch/salaryinfo, was used for this purpose. They appear in the table below:

	Low (10%)	High (90%)	Mean	Conversion factor
Auto electrician, car industry	2.784	5.848	4.316	1,0
Design engineer, car industry	3.988	7.302	5.645	1,3
IT analyst	4.826	10.761	7.794	1,8

Proposed unit: **Number of skilled positions required**

Procedure:

1. Define the baseline scenario to be used for benchmarking purposes
2. Estimate the number of net positions in the following specialties that the up-scaled project is expected to require in comparison to the baseline scenario:
    A. EV technicians
    B. EV design engineers
    C. IT analysts or other Industry 4.0 experts
3. Transform these into EV technician equivalent positions (N_{teq}) through the formula:

$$N_{teq} = 1.0\ A + 1.3\ B + 1.8\ C$$

Note that the definition of N_{teq} can be brought closer to the demonstration city realities by introducing conversion factors that reflect the local salaries. In fact, the data source cited above provides information for all countries around the world. It is also worth noting that the skill requirements of this indicator can be seen as overlapping with the job creation KPI of the previous heading on the assumption that the skill requirements are met with appropriate hiring. This overlap, however, is only partial as the unskilled labour of N_{NET} does not enter N_{teq}. Furthermore, N_{teq} provides the connection with the WP2 of SOLUTIONSplus that deals with the training needs associated with the project interventions.

A value function will be needed to transform the number of skilled positions as calculated above into the 5-point scale of the evaluation framework.

solutions plus