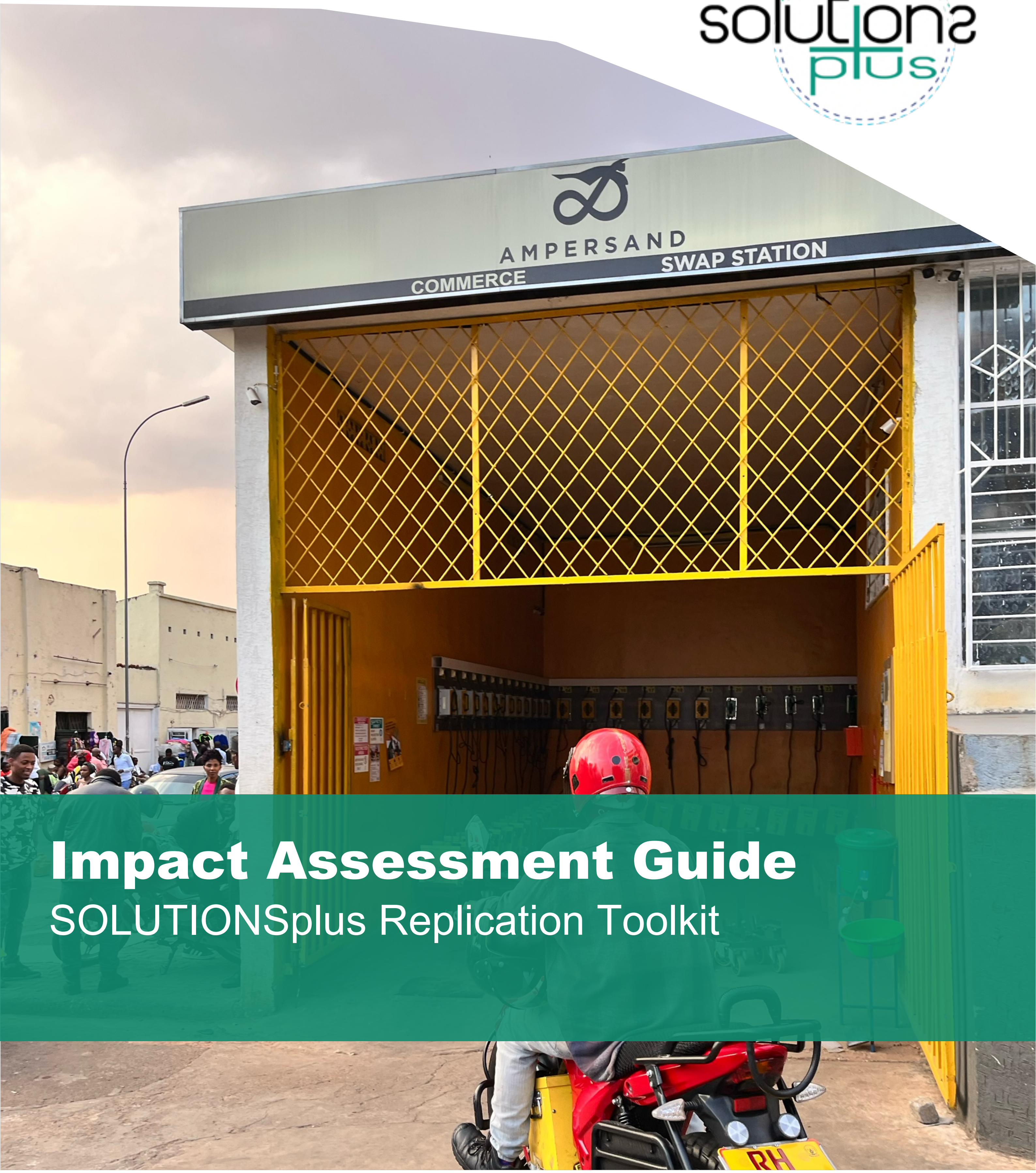

Impact Assessment Guide

SOLUTIONSplus Replication Toolkit

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ABOUT

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TITLE

Impact Assessment Guide

AUTHORS

Michael Barfod (DTU), George Panagakos (DTU)

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Review

Subash Dhar (UNEP), Oliver Lah (UEMI)

PICTURES

All the pictures are provided by the SOL+ partners

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List of abbreviations

BEV	Battery electric vehicle
CBA	Cost-benefit analysis
CER	Cost effectiveness ratio
CL	City Leader
CNG	Compressed natural gas
CO_2	Carbon dioxide
eMOB	e-mobility calculator (of UNEP)
EV	Electric vehicle
GDP	Gross domestic product
GHG	Greenhouse gas
ICE	Internal combustion engine
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal rate of return
KPI	Key performance indicator
LPG	Liquefied petroleum gas
MaaS	Mobility as a service
MCDA	Multi-criteria decision analysis
NOx	Nitrogen oxides
NPV	Net present value
PHEV	Plug-in hybrid electric vehicle
PKM	Passenger kilometres
PM	Particulate matter (2.5 or 10 depending on their maximum diameter)
PS	Performance standard
SDG	Sustainable development goal (in the context of the UN)
SMART	Simple multi-attribute rating technique
SOx	Sulphur oxides
TKM	Tonne kilometres
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)

1. Introduction

This report presents the work performed under Task 4.5 of the SOLUTIONSplus project. The report should be seen as a set of guidelines for performing the impacts assessment of demonstration activities. The content of the report is outlined below.

1.1. Our approach to impact assessment and evaluation

A few terms need to be defined before presenting the 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 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:

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

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 of interest in the city, i.e. e-mobility in urban 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 which, for compatibility purposes, needs to be identical for all demonstration cities. 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 as it is highly improbable that we will be able to locate data for the subsequent years. 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, 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.

1.2. Structure of the report

In addition to the present introduction, this report 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 presents the process for performing the ex ante assessment using examples from the demonstration activities. Section 4 presents the ex post assessment including examples. Finally, Section 5 presents the scaled-up project assessment illustrated by the comprehensive assessment performed for the Kathmandu demonstration activities.

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

A bankable up-scaled project promoting innovative and integrated e-mobility solutions in the urban transport of each demonstration city is the goal of 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

$[0 \le w_i \le 1]$ 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 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 2.1.

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 2.1 is provided in Appendix B and summarised in Table 2.1.

As shown in Figure 2.1, 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.

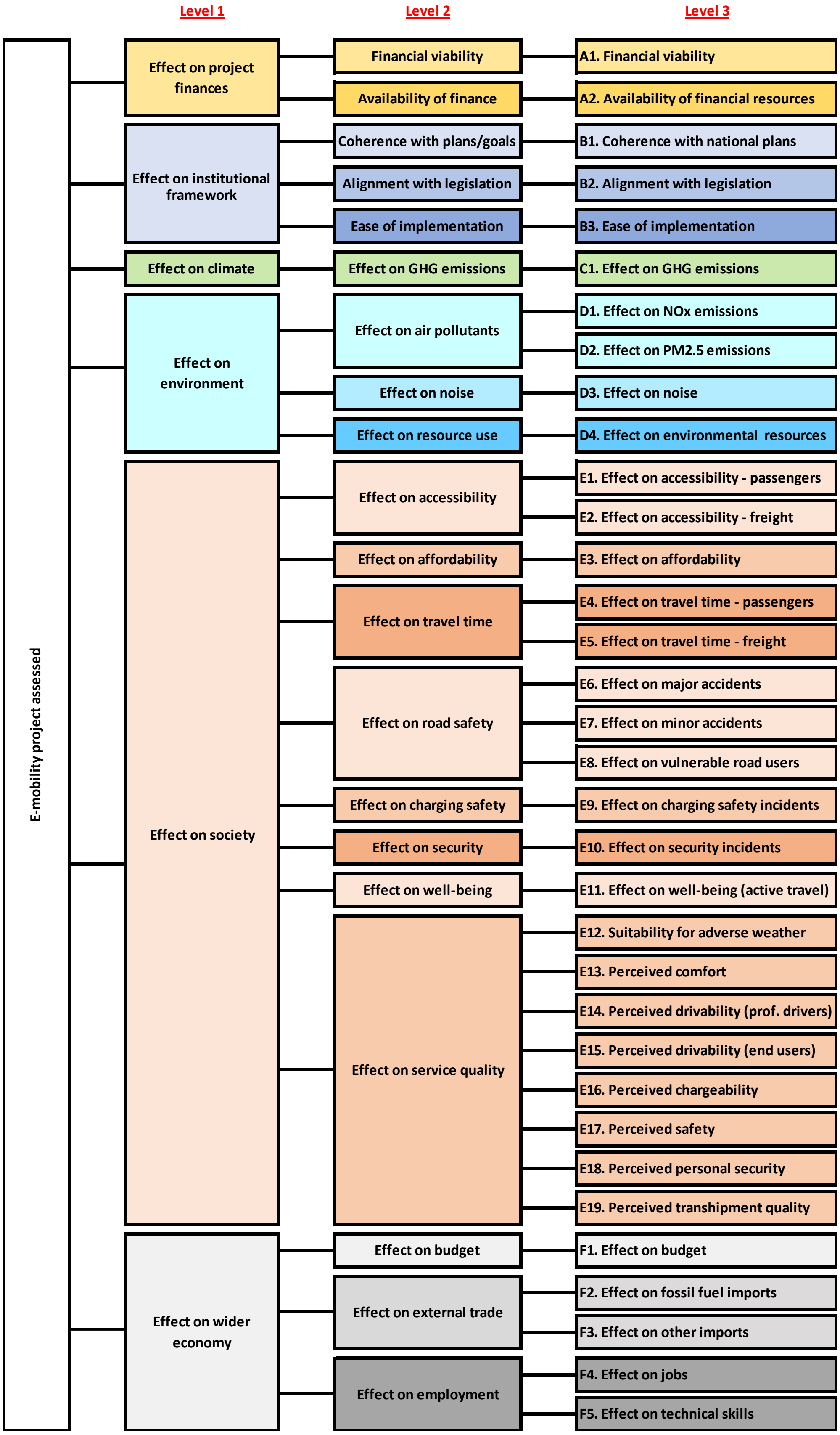

Figure 2.1 The SOLUTIONSplus attribute tree

Table 2.1 Definition of the indicators to be scored

KPI - Level 1	KPI - Level 2	KPI - Level 3	Unit of KPI level 3
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)
	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 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, the decision to include it in the attribute list was due to the fact that in some cases the planned demonstration projects aim at increasing the e-mobility friendliness of the institutional status quo.

Unlike the attributes of Figure 2.1, 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 2.2.

Table 2.2 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 2.1 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 Section 2.1.3.1. For qualitative attributes, the attribute values can be a number on a qualitative scale or direct ratings (refer to Section 2.1.3.2).

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:

$$\text{KPI value} = \text{Attribute value}_{(\text{up-scaled project})} - \text{Attribute value}_{(\text{baseline})}$$

In cases of attributes involving indicators (refer to Table 2.1) 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 Section 2.1.3.2.

2.1.3.1. *Estimation of attribute values*

The measurable indicators among the L3 KPIs of Table 2.1 are listed in Table 2.3. 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 in general 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 2.3 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

CO_2 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 CO_2 emissions from energy (IEA, 2020). The transport related CO_2 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, $PM_{2.5}$, PM_{10}, volatile organic compounds, etc.) which affect the local air quality and, therefore, are examined here together with CO_2. There are two approaches for calculating energy demand and CO_2 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 2.4 lists the data required for compiling the energy balances covering transport sector.

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[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 2.4 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

CO_2 emissions are calculated from the total fuel consumption based on the CO_2 content of fuels. National emission factors are published in National Communications, and Biennial Update Reports submitted to the UNFCCC.[3] If these are not available, default factors available from IPCC or other global databases should be used[4] (refer to Table 2.5). The top-down approach cannot however be used for estimating local pollutants.

Table 2.5 CO_2 emission coefficients for fossil fuels

Fuel	Giga gram CO_2/Petajoule	Kg CO_2/tonne of fuel	Kg CO_2/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

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

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

There are different tools and methodologies available for analysing the impacts of various mitigation actions on CO_2 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-

[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)

[5] https://unfccc.int/sites/default/files/resource/Transport_0.pdf

economic data (GDP and population), vehicle stock and sales, vehicle technology shares and techno-economic vehicle parameters. In addition to CO_2 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.

2.1.3.2. 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, 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

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

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, the former 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 2.2, 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.

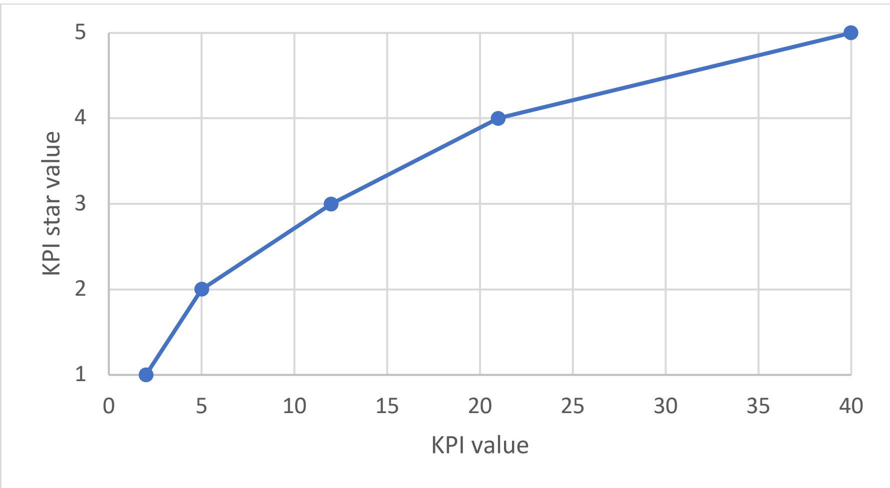


Figure 2.2 Example of a quantitative value function

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.

Figure 2.3 below provides an example of weights derived from the Kathmandu demonstration project. The figure exhibits the mean values of the weights received from the 15 stakeholders for all level 1 (L1), level 2 (L2) and level 3 (L3) attributes, as they have been calculated after applying the Delphi method for two rounds. Both **relative** (in black) and **cumulative** (in red) **weights** are shown. Relative weights indicate stakeholder priorities within a family and sum to 1. Cumulative weights at each level are determined by applying the relative weights of that level to the cumulative weight of the parent attribute. To minimise potential mistakes, the sum of all cumulative weights at each level is set to 100. The cumulative weights of L1 are identical to the corresponding relative ones, only expressed at a different scale.

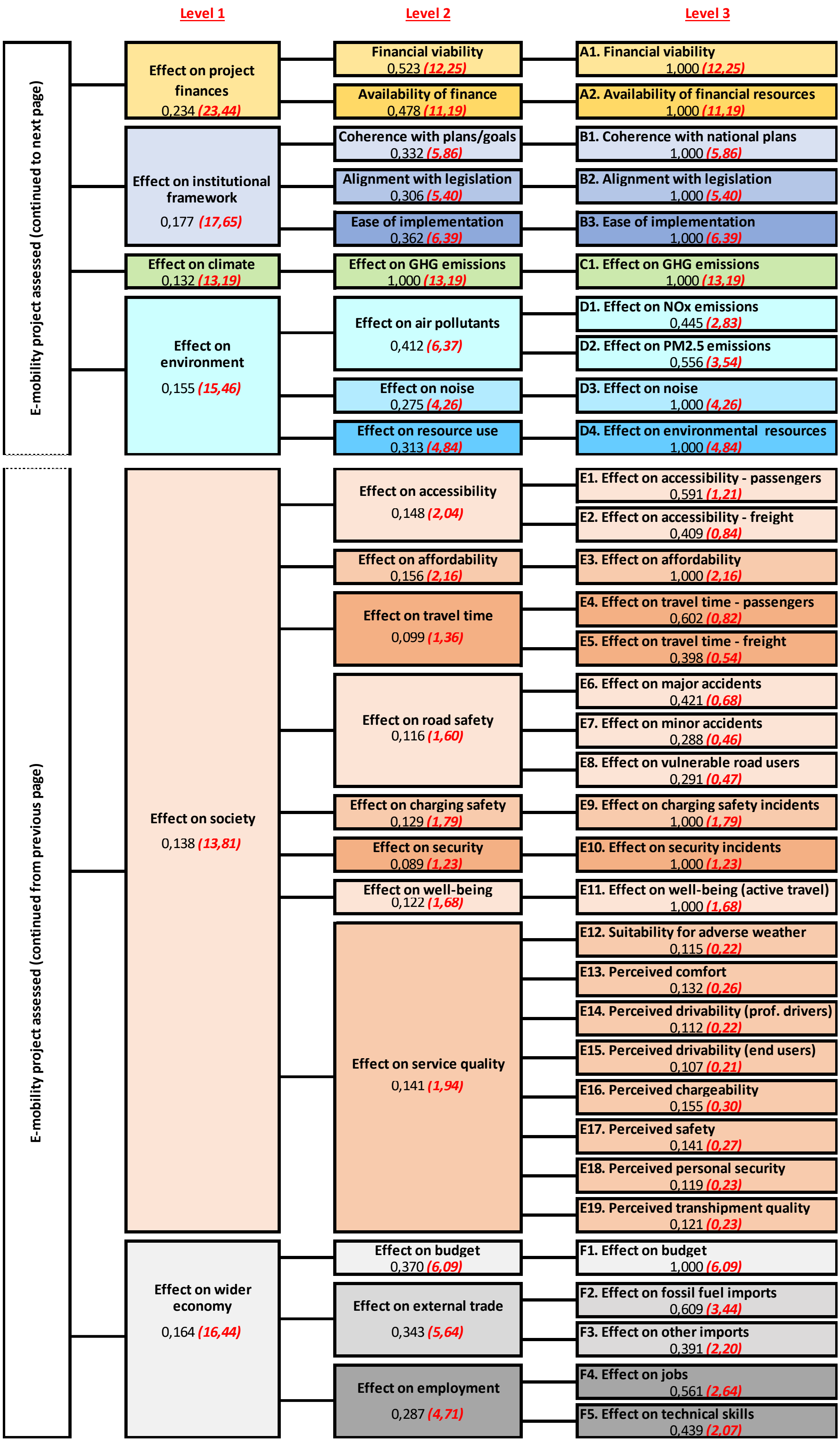


Figure 2.3. Attribute weights indicated by the Kathmandu stakeholders

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 views.

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 2.1 and the common KPIs of Table 2.2. 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 2.1 and common KPIs of Table 2.2.

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. Ex ante assessment

The following describes the indicators used for the ex ante assessment of demonstration activities. For each indicator, an example is provided from a specific city demonstration.

3.1. Financial Indicators

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.

3.1.1. 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. 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.

Example from Kathmandu

The financial viability of an investment in a remodelled Safa Tempo is assessed from an investor‘s perspective. The investor has no connection to the old vehicle, which is bought and remodelled by the manufacturer before being sold.

The calculations are shown in Table 3.1. The resulting NPV (3.36 million NPR indicates a very profitable investment before taxes. A value function was not created for the NPV in the Kathmandu case, but if so, the star value could be derived directly from this.

Table 3.1. Financial indicators for the remodelled Safa Tempo (Investor's perspective)

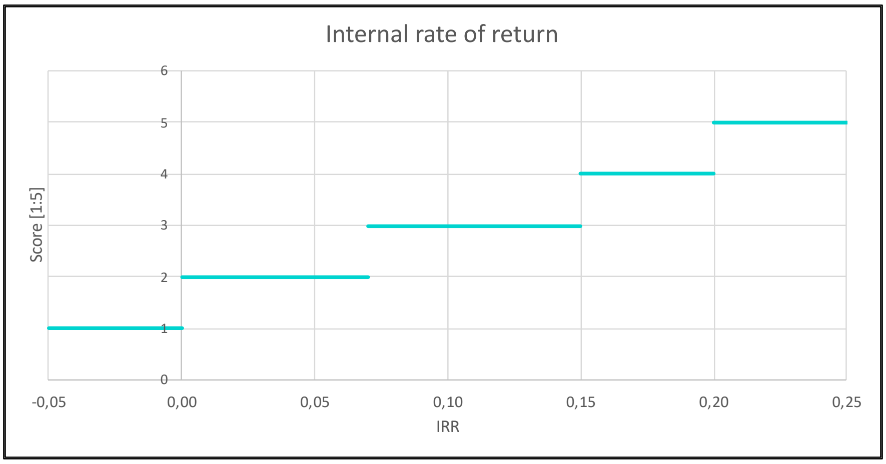
Remodelled Safa Tempo - Passenger service - Investor's perspective - Calculations							
Discount rate	10%						
	Y0	Y1	Y2	Y3	Y4	Y5	Y6
Year	2022	2023	2024	2025	2026	2027	2028
Investment	-1.950.000						
Residual value							231.000
Annual revenues		1.650.000	1.650.000	1.650.000	1.650.000	1.650.000	1.650.000
Annual operating & maintenance costs		-444.627	-451.469	-458.597	-466.022	-473.756	-481.813
Net pre-tax cash flow	-1.950.000	1.205.373	1.198.531	1.191.403	1.183.978	1.176.244	1.399.187
Cumulative pre-tax cash flow	-1.950.000	-744.627	453.904	1.645.307	2.829.285	4.005.528	5.404.716
Year	0	1	2	3	4	5	6
Pre-tax NPV	3.360.266						
Pre-tax IRR	57,81%						
Pre-tax payback (years)	1,62						
INCOME TAX RATE OF 25%							
Depreciation		-171.900	-154.710	-139.239	-125.315	-112.784	-101.505
Book value		1.778.100	1.623.390	1.484.151	1.358.836	1.246.052	1.144.547
Taxable income		1.033.473	1.043.821	1.052.164	1.058.663	1.063.460	153.135
Income tax		-258.368	-260.955	-263.041	-264.666	-265.865	-38.284
Net after-tax cash flow	-1.950.000	947.005	937.575	928.362	919.312	910.379	1.360.903
Cumulative after-tax cash flow	-1.950.000	-1.002.995	-65.419	862.942	1.782.255	2.692.633	4.053.537
Year	0	1	2	3	4	5	6
After-tax NPV	2.344.632						
After-tax IRR	43,55%						
After-tax payback (years)	2,07						
ALTERNATIVELY: FLAT INCOME TAX OF 7,500 NPR							
Income tax		-7500	-7500	-7500	-7500	-7500	-7500
Net after-tax cash flow	-1.950.000	1.197.873	1.191.031	1.183.903	1.176.478	1.168.744	1.391.687
Cumulative after-tax cash flow	-1.950.000	-752.127	438.904	1.622.807	2.799.285	3.968.028	5.359.716
Year	0	1	2	3	4	5	6
After-tax NPV	3.327.602						
After-tax IRR	57,38%						
After-tax payback (years)	1,63						

3.1.2. Internal Rate of Return (IRR)

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.

Example from Kathmandu

Compared to NPV, IRR exhibits the advantage of being independent from the size of the investment. It was, thus, decided to construct a value function only for this indicator. The suggested function transforming the IRR (expressed in %) into a star value as required by the evaluation framework is shown in Figure 3.2.



1 star	IRR ≤ 0%
2 stars	0% < IRR ≤ 7%
3 stars	7% < IRR ≤ 15%
4 stars	15% < IRR ≤ 20%
5 stars	IRR > 20%

Figure 3.2. Value function for the IRR

The calculations in Table 3.1 shows a IRR above 43% for all scenarios. Thus, according to Figure 3.2, the investment receives a 5-star value.

3.1.3. 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.

Example from Kathmandu

In the example presented in Table 3.1, the maximum payback period is 2.07 years. A value function was not created for the payback period in the Kathmandu case, but if so, the star value could be derived directly from this.

Cost minimising projects

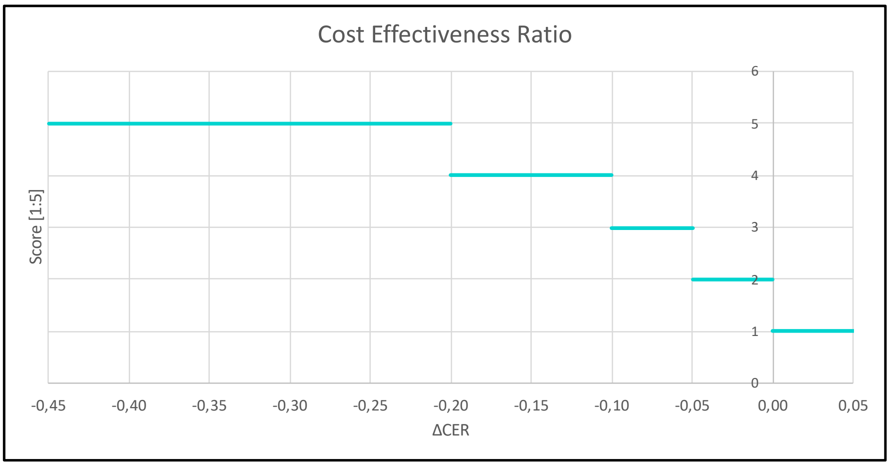
There are projects, mainly in the public sector, where revenues either do not exist or are very difficult to monetize. The Cost Effectiveness Ratio (CER) is the appropriate indicator for such cases.

3.1.4. Cost Effectiveness Ratio (CER)

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.

Example from Kathmandu

The difference of the CER value of the assessed solution from that of the old solution, denoted as ΔCER and expressed as a percentage of the old solution's CER value, is the attribute that needs to be transformed into a star value. This is shown in Figure 3.3.



1 star	ΔCER ≥ 0%
2 stars	-5% ≤ ΔCER < 0%
3 stars	-10% ≤ ΔCER < -5%
4 stars	-20% ≤ ΔCER < -10%
5 stars	ΔCER < -20%

ΔCER: Percentage difference in CER values

Figure 3.3. Value function for the CER

The example calculates the CER for a demo component concerning the activity of primary waste collection, defined as the collection and carriage of waste from households to a consolidation site using light vehicles.

The vehicle used for benchmarking is a petrol-driven 3-wheeler with a payload capacity of 350 kg and 4.70 cu.m. in volume terms. Table 3.2 presents the CER calculations for the petrol driven vehicle.

Given that a pick-up truck would provide the needed cargo volume, it was decided to convert an existing vehicle into EV. An LFP battery of 7 kWh would be sufficient for driving about 50 km daily, necessary for exhausting the capacity of the vehicle (5.65 cu.m.). After 6 years, the battery has to be replaced with a new one, enabling operations for a total of 12 years. Table 3.3 presents the corresponding CER calculation. The annualised capital cost of the converted vehicle is much higher than that of the 3W, but most of the difference is covered by more favourable operational cost. When accounting for the higher volumetric capacity, the converted EV exhibits a CER value of 474.92 NPR/cu.m., which constitutes a 13.52% improvement in relation to the petrol-driven 3W (ΔCER). Thus, using the value function in Figure 3.3, the converted 4-wheeler receives 4 stars on the scale.

Table 3.2. CER calculation for the waste collector (petrol-run 3-wheeler)

Petrol-run 3-wheeler - waste collector				
Category	**Parameter**	**Value**	**Units**	**Comments**
General info	Year built	2017		
	Waste payload	350	kg	
	Waste volume	4,704	cu.m.	
Propulsion	ICE - petrol			
	Engine size	250	cc	
Capital cost	Purchase price	968.775	NPR	750.000 NPR in 2017 prices, inflated by 29,17% (2017-2022)
				https://www.macrotrends.net/countries/NPL/nepal/inflation-rate-cpi
				https://take-profit.org/en/statistics/inflation-rate/nepal/
	Expected useful life	12	years	
	Residual value	45.000	NPR	
	Discount rate	10%		
Operational profile	Average distance/day	40	km/day	
	Operating days/year	320	days/year	
Yearly operating cost	Total operating cost	686.563	NPR/year	(=sum(C37:C41)+C45+C55+C56)
	* Licencing/renewal	900	NPR/year	(=4.500 NPR for 5 years)
	* Technical inspection	0	NPR/year	
	* Insurance	0	NPR/year	
	* Personnel cost	420.000	NPR/year	(monthly salary of 35.000 NPR)
	* Fuel cost	172.563	NPR/year	(=C34/C42*C35*C44)
	- Fuel consumption	13,5	km/lt	(Based on field study)
	- Petrol price	182	NPR/lt	(as of Aug. 2022)
	* Maintenance cost	71.500	NPR/year	(=sum(C46:C54))
	- Tires	18.000	NPR/year	(once per year)
	- Brake shoes	2.000	NPR/year	
	- Dent paint	12.000	NPR/year	(=36.000 every 3 years)
	- Wiring	0	NPR/year	
	- Head- & tail-lights	0	NPR/year	
	- Fuses	500	NPR/year	
	- Display system	3.000	NPR/year	
	- Throttle pedal	1.000	NPR/year	
	- Engine service	35.000	NPR/year	(oil change, normal engine overhaul, other minor servicing)
	* Vehicle cleaning	21.600	NPR/year	(=450 NPR/cleaning, 4 times per month)
	* Other	0	NPR/year	
Annualized cost	Capital	140.076	NPR/year	(=(C23-C30/(1+C33)^C27)/(1/C33-1/(C33*(1+C33)^C27)))
	Operational	686.563	NPR/year	(=C36)
	Total	826.639	NPR/year	(=C57+C58)
Annual waste collected	Volume of waste	1.505	cu.m./year	(=C19*C35)
Cost effectiveness ratio (CER)		**549,16**	NPR/cu.m.	(=C59/C60)

Table 3.4. CER calculation for the waste collector (converted 4-wheeler)

Converted 4-wheeler - waste collector				
Category	**Parameter**	**Value**	**Units**	**Comments**
General info	Year built	2023		
	Waste payload	1.200	kg	
	Waste volume	5,65	cu.m.	
Propulsion	Battery type	LFP		
	Battery size	7	kWh	Only 80% (=5.6 kWh) can be used before recharging
	Number of batteries	1		
Capital cost	Purchase price	2.050.000	NPR	(=K24+K25+K26)
	* Manufacturing	1.050.000	NPR	
	* Drive train	550.000	NPR	
	* Battery	450.000		
	Expected useful life	12	years	
	* Vehicle body	12	years	
	* Battery	6	years	(based on about 2.000 charging cycles of the battery)
	Residual value	299.000	NPR	(=K31+K32)
	* Body	250.000	NPR	Scrap price after 12 years.
	* Battery	49.000	NPR	After 6 years (7.000 NPR/kWh for healthy battery cells).
	Discount rate	10%		
Operational profile	Average distance/day	50	km/day	
	Operating days/year	320	days/year	
Yearly operating cost	Total operating cost	538.557	NPR/year	(=sum(K37:K41)+K45+K55+K56)
	* Licencing/renewal	900	NPR/year	(=4.500 NPR for 5 years)
	* Technical inspection	2.500	NPR/year	
	* Insurance	25.000	NPR/year	
	* Personnel cost	420.000	NPR/year	(monthly salary of 35.000 NPR)
	* Electricity cost	13.857	NPR/year	(=equivalent annual cost)
	- Energy consumption	0,112	kWh/km	(on the assumption of 5,6 kWh for 50 km)
	- Battery efficiency	100,000	%	(3% drop in efficiency per year)
	- Electricity tariff	7	NPR/kWh	(special tariff for EVs)
	* Maintenance cost	47.500	NPR/year	(=sum(K46:K54))
	- Tires	10.000	NPR/year	(=40.000 every 4 years)
	- Brake shoes	2.000	NPR/year	
	- Dent paint	15.000	NPR/year	(=60.000 every 4 years)
	- Wiring	4.500	NPR/year	
	- Head- & tail-lights	3.000	NPR/year	
	- Fuses	500	NPR/year	
	- Suspension	10.000	NPR/year	
	- Throttle pedal	1.500	NPR/year	
	- Motor service	1.000	NPR/year	
	* Vehicle cleaning	28.800	NPR/year	(=600 NPR/cleaning, 4 times per month)
	* Other	0	NPR/year	
Annualized cost	Capital	320.103	NPR/year	(=(K23+(K26-K32)/(1+K33)^K29-K30/(1+K33)^K27)/(1/K33-1/(K33*(1+K33)^K27))
	Operational	538.557	NPR/year	(=K36)
	Total	858.660	NPR/year	(=K57+K58)
Annual waste collected	Volume of waste	1.808	cu.m./year	(=K19*K35)
Cost effectiveness ratio (CER)		**474,92**	NPR/cu.m.	(=K59/K60)

3.1.5. 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.

Table 3.5. Evaluation of the availability of financial resources

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 stakeholders evaluate the KPI using the evaluation scale above, and the score directly enters the evaluation framework.

Example from Kathmandu

Table 3.6 below presents the evaluation of the KPI for the Kathmandu components. In the "justification" column reference is made to specific documents supporting the assessment (for more information, see D1.6 Volume 4). The scores in the table are identical to the star values that enter the evaluation framework directly.

Table 3.6. Evaluation parameters for Kathmandu

A.2 Availability of financial resources									
Evaluation parameters		**Converted bus**		**Remodelled e3W pax**		**Remodelled e3W cargo**		**New e3W design pax**	
		Answer	**Justification**	**Answer**	**Justification**	**Answer**	**Justification**	**Answer**	**Justification**
A.	Availability of government/regional/city funds for supporting the project	Yes	[1] [2] [3] [4]	Yes	[4]	Yes	[4]	Yes	[4]
B.	Intention of international donors to get involved in funding e-mobility projects of the suggested nature	Yes	[5] [6]	Yes	[7]	No		Yes	[7]
C.	Preparedness of commercial banks to support projects concerning e-mobility in the project city through preferential interest rates	No	[9] [10]	Yes	[8]	No		Yes	[8]
SCORE		**3**		**5**		**2**		**5**	
Evaluation parameters		**New e3W design cargo**		**Converted e4W waste**		**Converted truck**		**New e-Shuttle van**	
		Answer	**Justification**	**Answer**	**Justification**	**Answer**	**Justification**	**Answer**	**Justification**
A.	Availability of government/regional/city funds for supporting the project	Yes	[4]	Yes	[4]	Yes	[4]	Yes	[4]
B.	Intention of international donors to get involved in funding e-mobility projects of the suggested nature	No		No		No		Yes	[5] [6]
C.	Preparedness of commercial banks to support projects concerning e-mobility in the project city through preferential interest rates	No		No		No		No	[9] [10] [11]
SCORE		**2**		**2**		**2**		**3**	

3.2. Institutional/political indicators

3.2.1. Coherence with national plans and development goals

This KPI examines the coherence of the activities with national plans and development goals. The evaluation is performed qualitatively using the parameters outline in Table 3.7.

Table 3.7. Evaluation of the availability of 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 stakeholders evaluate the KPI using the evaluation scale above, and the score directly enters the evaluation framework.

Example from Kathmandu

Table 3.8 below presents the evaluation of the KPI for the Kathmandu components. In the "justification" column reference is made to specific documents supporting the assessment (for more information, see D1.6 Volume 4). The scores in the table are identical to the star values that enter the evaluation framework directly.

Table 3.8. Evaluation parameters for Kathmandu

B.1 Coherence with national plans and development goals									
Evaluation parameters		**Converted bus**		**Remodelled e3W pax**		**Remodelled e3W cargo**		**New e3W design pax**	
		Answer	**Justification**	**Answer**	**Justification**	**Answer**	**Justification**	**Answer**	**Justification**
A.	Alignment with **transport policy** at national or city level (e.g., National Transport Plan, City Master Plans, etc.)	Yes	[1] [2] [3] [4]	Yes	[2] [3] [4]	Yes	[2] [4]	Yes	[2] [3] [4]
B.	Alignment with **energy policy** at national level (e.g., Energy Performance / Efficiency Standards, etc.)	Yes	[5] [9]	Yes	[5] [9]	Yes	[5] [9]	Yes	[5] [9]
C.	Alignment with **environment policy** at national or city level (e.g., emission standards, waste and recycling policies)	Yes	[6] [7] [10]	Yes	[6] [10]	Yes	[6] [10]	Yes	[6] [10]
D.	Alignment with **overarching policies** at national level (e.g., National Development Plans, Climate Action Plans, NDCs)	Yes	[8] [10] [11]	Yes	[8] [10] [11]	Yes	[8] [10]	Yes	[8] [10] [11]
SCORE		**5**		**5**		**5**		**5**	
Evaluation parameterss		**New e3W design cargo**		**Converted e4W waste**		**Converted truck**		**New e-Shuttle van**	
		Answer	**Justification**	**Answer**	**Justification**	**Answer**	**Justification**	**Answer**	**Justification**
A.	Alignment with **transport policy** at national or city level (e.g., National Transport Plan, City Master Plans, etc.)	Yes	[2] [4]	Yes	[2] [4]	Yes	[2] [4]	Yes	[2] [4]
B.	Alignment with **energy policy** at national level (e.g., Energy Performance / Efficiency Standards, etc.)	Yes	[5] [9]	Yes	[5] [9]	Yes	[5] [9]	Yes	[5] [9]
C.	Alignment with **environment policy** at national or city level (e.g., emission standards, waste and recycling policies)	Yes	[6] [10]	Yes	[6] [10]	Yes	[6] [10]	Yes	[6] [7] [10]
D.	Alignment with **overarching policies** at national level (e.g., National Development Plans, Climate Action Plans, NDCs)	Yes	[8] [10]	Yes	[8] [10]	Yes	[8] [10]	Yes	[8] [10] [11]
SCORE		**5**		**5**		**5**		**5**	

3.2.2. Alignment with supra-national/national/city legislation and 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 in Table 3.9 below:

Table 3.9. Assessment scale fort he alignment with supra-national/national/city legislation and regulations.

	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.

Example from Kathmandu

Table 3.10 below presents the evaluation of the KPI for the Kathmandu components. In the “justification” column reference is made to specific documents supporting the assessment (for more information, see D1.6 Volume 4). The scores in the table are identical to the star values that enter the evaluation framework directly.

Table 3.10. Evaluation parameters for Kathmandu

B.2 Alignment with supra-national/national/city legislation & regulations									
	Evaluation parameters	**Converted bus**		**Remodelled e3W pax**		**Remodelled e3W cargo**		**New e3W design pax**	
		Answer	**Justification**	**Answer**	**Justification**	**Answer**	**Justification**	**Answer**	**Justification**
A.	**Full compliance:** It can be ascertained that the relevant project element/s is/are fully compliant with regulation	No	-	No	-	No	-	No	-
B.	**Presence of uncertainty:** Situations wherein it cannot fully be ascertained whether the relevant element/s of the proposed project is 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)	Yes	[1] [2] [3]	Yes	[2] [3] [4]	Yes	[2] [3]	Yes	[2] [3] [4]
C.	**Non-compliance:** It can be ascertained that the relevant project element/s would not comply with the regulation	No	-	No	-	No	-	No	-
SCORE		**2**		**2**		**3**		**2**	
	Evaluation parameters	**New e3W design cargo**		**Converted e4W waste**		**Converted truck**		**New e-Shuttle van**	
		Answer	**Justification**	**Answer**	**Justification**	**Answer**	**Justification**	**Answer**	**Justification**
A.	**Full compliance:** It can be ascertained that the relevant project element/s is/are fully compliant with regulation	No	-	No	-	No	-	No	-
B.	**Presence of uncertainty:** Situations wherein it cannot fully be ascertained whether the relevant element/s of the proposed project is 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)	Yes	[2] [3]	Yes	[1] [2] [3]	Yes	[1] [2] [3]	Yes	[2] [3]
C.	**Non-compliance:** It can be ascertained that the relevant project element/s would not comply with the regulation	No	-	No	-	No		No	
SCORE		**3**		**2**		**2**		**3**	

3.2.3. Ease of implementation (in terms of administrative barriers)

This KPI examines the administrative barriers of implementing the proposed activities. The evaluation is performed qualitatively using the parameters outline in Table 3.11.

Table 3.11. Evaluation of the ease of implementation

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.

Example from Kathmandu

Table 3.12 below presents the evaluation of the KPI for the Kathmandu components. In the "justification" column reference is made to specific documents supporting the assessment (for more information, see D1.6 Volume 4). The scores in the table are identical to the star values that enter the evaluation framework directly.

Table 3.12. Evaluation parameters for Kathmandu

B.3 Ease of implementation (in terms of administrative barriers)									
Evaluation parameters		Converted bus		Remodelled e3W pax		Remodelled e3W cargo		New e3W design pax	
		Answer	Justification	Answer	Justification	Answer	Justification	Answer	Justification
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	Yes	[1] [2]	Yes	[2]	Yes	[2]	Yes	[2]
B.	The political and institutional bodies needed for supporting the implementation of the project are in place	Yes	[3] [4]	Yes	[3] [4]	Yes	[3] [4]	Yes	[3] [4]
C.	The existing national/city political and institutional bodies are (likely to be) supportive of the necessary actions required for the project implementation	No	[5]	No	[5]	No	[5]	No	[5]
SCORE		3		3		3		3	
Evaluation parameters		New e3W design cargo		Converted e4W waste		Converted truck		New e-Shuttle van	
		Answer	Justification	Answer	Justification	Answer	Justification	Answer	Justification
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	Yes	[2]	Yes	[1] [2]	Yes	[1] [2]	Yes	[2]
B.	The political and institutional bodies needed for supporting the implementation of the project are in place	Yes	[3] [4]	Yes	[3] [4]	Yes	[3] [4]	Yes	[3] [4]
C.	The existing national/city political and institutional bodies are (likely to be) supportive of the necessary actions required for the project implementation	No	[5]	No	[5]	No	[5]	No	[5]
SCORE		3		3		3		3	

3.3. Climate-related indicators

3.3.1. 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.

Example from Kathmandu

A converted 4 wheeler is compared to a petrol-driven pick-up truck. As a waste collector, the vehicle is expected to cover 16,000 km/year (= 50 km/day x 320 days/year). On the other hand, as a pick-up truck, it used to run for 23,100 km/year. Therefore, an adjustment factor of 0.6926 should be applied to its previous fuel consumption (of 1,925 lt/year), resulting in an estimated savings of 1,333 lt of petrol annually.

Assuming a well-to-wheel (WtW) CO_2 factor of 3,000 gr/lt (e-Mob default value), the above-estimated amount of fuel corresponds to 4.00 tonnes of CO_2 emissions saved per unit of converted 4-wheeler.

3.4. Environmental indicators

Effect on air pollutants

3.4.1. 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.

Example from Kathmandu

A converted 4 wheeler is compared to a petrol-driven pick-up truck. As a waste collector, the vehicle is expected to cover 16,000 km/year (= 50 km/day x 320 days/year). On the other hand, as a pick-up truck, it used to run for 23,100 km/year. Therefore, an adjustment factor of 0.6926 should be applied to its previous fuel consumption (of 1,925 lt/year), resulting in an estimated savings of 1,333 lt of petrol annually.

Based on Shrestha et al. (2013), the NOx emissions factor for light duty vehicles in the Kathmandu valley is estimated at 13.76 gr/lt. The application of this factor on the annual fuel consumption estimated above results in a figure of 18.35 kg of NOx emissions abated annually per unit of converted vehicle.

3.4.2. $PM_{2.5}$ 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.

Example from Kathmandu

A converted 4 wheeler is compared to a petrol-driven pick-up truck. As a waste collector, the vehicle is expected to cover 16,000 km/year (= 50 km/day x 320 days/year). On the other hand, as a pick-up truck, it used to run for 23,100 km/year. Therefore, an adjustment factor of 0.6926 should be applied to its previous fuel consumption (of 1,925 lt/year), resulting in an estimated savings of 1,333 lt of petrol annually.

The $PM_{2.5}$ emissions factor for this type of fuel and vehicle is 18.92 gr/lt (Das et al., 2022). The mass of abated $PM_{2.5}$ emissions annually per unit of converted 4W then becomes 25.23 kg.

4. Ex post assessment

4.1. Environmental indicators

4.1.1. 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.

Table 4.1. Noise impact

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).

Example from Kathmandu

At the time of drafting this document, the noise measurements had not been finalised.

4.1.2. 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[7]. The KPI is assessed using the evaluation criteria outlined in Table 4.2.

Table 4.2. Evaluation of environmental resources

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 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.

Example from Kathmandu

Table 4.3 below presents the evaluation of the KPI for the Kathmandu components. In the "justification" column reference is made to specific documents supporting the assessment

[7] 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.

(for more information, see D1.6 Volume 4). The scores in the table are identical to the star values that enter the evaluation framework directly.

Table 4.3. Evaluation parameters for Kathmandu

D.4 Effect on environmental resources									
Evaluation parameters		**Converted bus**		**Remodelled e3W pax**		**Remodelled e3W cargo**		**New e3W design pax**	
		Answer	**Justification**	**Answer**	**Justification**	**Answer**	**Justification**	**Answer**	**Justification**
A.	Useful application of materials through **recycling** and/or **recovering**	Yes	[1]	Yes	[1]	Yes	[1]	No	[2]
B.	Smarter vehicle use and manufacturing through **rethinking** and/or **reducing**	No	[3] [4]	No	[3] [4]	No	[3] [4]	No	[3] [4]
C.	Expanded lifespan of vehicles and parts through **reusing**, **repairing** and/or **remanufacturing**	Yes	[5]	Yes	[5]	Yes	[5]	No	[6]
SCORE		**5**		**5**		**5**		**1**	
Evaluation parameters		**New e3W design cargo**		**Converted e4W waste**		**Converted truck**		**New e-Shuttle van**	
		Answer	**Justification**	**Answer**	**Justification**	**Answer**	**Justification**	**Answer**	**Justification**
A.	Useful application of materials through **recycling** and/or **recovering**	No	[2]	Yes	[1]	Yes	[1]	No	[2]
B.	Smarter vehicle use and manufacturing through **rethinking** and/or **reducing**	No	[3] [4]	No	[3] [4]	No	[3] [4]	No	[3] [4]
C.	Expanded lifespan of vehicles and parts through **reusing**, **repairing** and/or **remanufacturing**	No	[6]	Yes	[5]	Yes	[5]	No	[6]
SCORE		**1**		**5**		**5**		**1**	
Notes									
[1]	Conversion and remodelling activities enable the recycling of materials that can be used for same or other purposes.								
[2]	New designs offer fewer opportunities for material recycling. The recycling of the battery is a possibility which, however, needs to be pursued at national level, as presently there is no such infrastructure.								
[3]	The vehicles do not incorporate advanced technology, eco-friendly materials, or other features that promote intelligent vehicle use. They lack smart systems such as predictive maintenance, optimised routing, or energy-efficient driving assistance, which could contribute to more sustainable and efficient vehicle operations.								
[4]	The manufacturing processes still rely on conventional practices that contribute to resource depletion and waste generation.								
[5]	By definition, conversion and remodelling activities involve reusing and remanufacturing of vehicles and parts.								
[6]	No special provision is made for the new designs for reusing, repairing and/or remanufacturing activities.								

4.2. Social indicators

4.2.1. 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.[8]

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; see Table 4.4 below.

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

Table 4.4. City values for reaching the indicator goal.

City	SDG 11.2 value, official value from UN Habitat[9]	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.

Table 4.5. Qualitative judgment of pick-up operations

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.

4.2.2. 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).[10] The prices are to be quoted in local currencies.

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

[10] 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

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;[11] 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.[12]

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.

Example from Kathmandu

No effect on accessibility is expected by the planned initiatives.

4.2.3. 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

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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.

[11] 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.

[12] 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).

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
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.

Example from Kathmandu

Possible effect due to improved reliability of e-buses in comparison to diesel ones.

4.2.4. 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 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)**

Table 4.6. Evaluation of road accidents with fatalities/serious injuries

Question	**Please estimate the potential impact of the proposed up-scaled project in terms of number of road accidents with fatalities/serious injuries 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)**

Table 4.7. Evaluation of road accidents with minor injuries/material damage

Question	**Please estimate the potential impact of the proposed up-scaled project in terms of the number of road accidents with minor injuries/material damage 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).**

Table 4.8. Evaluation of road accidents involving vulnerable road users

Question	**Please estimate the potential impact of the proposed up-scaled project in terms of the <u>number of road accidents involving VRUs</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 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.

<u>A. Traffic related near accidents/dangerous situations</u>

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.**

Table 4.9. Evaluation of traffic related near accidents/dangerous situation

Question	**Please estimate the potential impact of the proposed up-scaled project in terms of the <u>number of near accidents and dangerous situations</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 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.**

Table 4.10. Evaluation of traffic related near accidents/dangerous situations involving VRUs

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.

Example from Kathmandu

Table 4.11-4.13 below presents the evaluation of the KPI for the Kathmandu components. In the "justification" column reference is made to specific documents supporting the assessment (for more information, see D1.6 Volume 4). The scores in the table are identical to the star values that enter the evaluation framework directly.

Table 4.11. Road accidents with fatalities/serious injuries, Kathmandu

E.6 Road accidents with fatalities / serious injuries								
Evaluation parameters	**Converted bus**		**Remodelled e3W pax**		**Remodelled e3W cargo**		**New e3W design pax**	
	Answer	**Justification**	**Answer**	**Justification**	**Answer**	**Justification**	**Answer**	**Justification**
Effect on road accidents with fatalities / serious injuries	Slight improvement	[1] [4] [5] [8] [11]	No change	[2] [4] [6] [9] [12]	No change	[2] [4] [6] [9] [12]	No change	[2] [4] [6] [9] [12]
SCORE (7-point scale in parenthesis)	**4** (5.20)		**3** (4.40)		**3** (4.20)		**3** (4.40)	
Evaluation parameters	**New e3W design cargo**		**Converted e4W waste**		**Converted truck**		**New e-Shuttle van**	
	Answer	**Justification**	**Answer**	**Justification**	**Answer**	**Justification**	**Answer**	**Justification**
Effect on road accidents with fatalities / serious injuries	No change	[2] [4] [6] [9] [12]	Slight improvement	[1] [4] [5] [8] [11]	Slight improvement	[1] [4] [5] [8] [11]	Slight improvement	[3] [4] [7] [10] [13]
SCORE (7-point scale in parenthesis)	**3** (4.20)		**4** (5.20)		**4** (5.20)		**4** (4.80)	

Notes		**Interviewees**
[1]	If conversion is standardised and protocols are followed, converted vehicles compared to their equivalent ICE-run ones can exhibit improved road safety because of lower chances of component damage.	[I.1]
[2]	Remodelled and newly designed e3Ws are likely to be safer in comparison to the old solutions because of better comfort features and better stability in offroad conditions due to battery placement.	[I.1]
[3]	E-shuttle vans are safer to travel because of their locally manufactured rigid body frame.	[I.1]
[4]	In terms of road safety the performance remains unaltered for any vehicle type (bus conversion , 3-wheelers, e-shuttle van & truck conversions). The assessment would have been different if the environmental perspective was considered.	[I.2]
[5]	The converted vehicles (bus & truck) will be safer compared to their ICE equivalents due to fewer moving parts leading to fewer failures.	[I.3]
[6]	New 3W are likely to be better in terms of road safety. For example, old safa tempos (old solution) were unsafe because of stability issues due to uneven battery or cylinder placement. On the contrary, their remodelled and newly designed version has better stability because of battery placement.	[I.3]
[7]	E-shuttle van has well designed interiors and ergonomic seating for safe travel.	[I.3]
[8]	The converted vehicles are safer if the conversion procedure is followed and quality is maintained.	[I.4]
[9]	The remodelled and newly designed e3Ws used for cargo can be unsafe because of load stablity issues. No changes are expected for the passenger use.	[I.4]
[10]	E-shuttle vans are safe to travel because of their robust casing structure, which is protective in case of an accident.	[I.4]
[11]	If standard conversion kit is used for the conversion, it is likely to have fewer accidents. If not, the number of accidents may rise.	[I.5]
[12]	Remodelled and newly designed e3Ws are still no safe when vehicle runs at speed more than 50 km/hr because of load stability issues at higher speeds.	[I.5]
[13]	E-shuttle vans are equally good with regular shuttle vehicles when it comes to road safety.	[I.5]

Table 4.12. Road accidents with minor injuries/material damage, Kathmandu

E.7 Road accidents with minor injuries / material damage								
Evaluation parameters	**Converted bus**		**Remodelled e3W pax**		**Remodelled e3W cargo**		**New e3W design pax**	
	Answer	**Justification**	**Answer**	**Justification**	**Answer**	**Justification**	**Answer**	**Justification**
Effect on road accidents with minor injuries / material damage	Slight improvement	[1] [4] [5] [8] [11]	No change	[2] [4] [6] [9] [12]	No change	[2] [4] [6] [9] [12]	No change	[2] [4] [6] [9] [12]
SCORE (7-point scale in parenthesis)	**4** (5.20)		**3** (4.40)		**3** (4.20)		**3** (4.40)	
Evaluation parameters	**New e3W design cargo**		**Converted e4W waste**		**Converted truck**		**New e-Shuttle van**	
	Answer	**Justification**	**Answer**	**Justification**	**Answer**	**Justification**	**Answer**	**Justification**
Effect on road accidents with minor injuries / material damage	No change	[2] [4] [6] [9] [12]	Slight improvement	[1] [4] [5] [8] [11]	Slight improvement	[1] [4] [5] [8] [11]	Slight improvement	[3] [4] [7] [10] [13]
SCORE (7-point scale in parenthesis)	**3** (4.20)		**4** (5.20)		**4** (5.20)		**4** (4.80)	

Notes		**Interviewees**
[1]	If conversion is standardised and protocols are followed, converted vehicles compared to their equivalent ICE-run ones can exhibit improved road safety because of lower chances of component damage.	[I.1]
[2]	Remodelled and newly designed e3Ws are likely to be safer in comparison to the old solutions because of better comfort features and better stability in offroad conditions due to battery placement.	[I.1]
[3]	E-shuttle vans are safer to travel because of their locally manufactured rigid body frame.	[I.1]
[4]	In terms of road safety the performance remains unaltered for any vehicle type (bus conversion , 3-wheelers, e-shuttle van & truck conversions). The assessment would have been different if the environmental perspective was considered.	[I.2]
[5]	The converted vehicles (bus & truck) will be safer compared to their ICE equivalents due to fewer moving parts leading to fewer failures.	[I.3]
[6]	New 3W are likely to be better in terms of road safety. For example, old safa tempos (old solution) were unsafe because of stability issues due to uneven battery or cylinder placement. On the contrary, their remodelled and newly designed version has better stability because of battery placement.	[I.3]
[7]	E-shuttle van has well designed interiors and ergonomic seating for safe travel.	[I.3]
[8]	The converted vehicles are safer if the conversion procedure is followed and quality is maintained.	[I.4]
[9]	The remodelled and newly designed e3Ws used for cargo can be unsafe because of load stablity issues. No changes are expected for the passenger use.	[I.4]
[10]	E-shuttle vans are safe to travel because of their robust casing structure, which is protective in case of an accident.	[I.4]
[11]	If standard conversion kit is used for the conversion, it is likely to have fewer accidents. If not, the number of accidents may rise.	[I.5]
[12]	Remodelled and newly designed e3Ws are still no safe when vehicle runs at speed more than 50 km/hr because of load stability issues at higher speeds.	[I.5]
[13]	E-shuttle vans are equally good with regular shuttle vehicles when it comes to road safety.	[I.5]

Table 4.13. Road accidents involving vulnerable road users, Kathmandu

E.8 Road accidents involving vulnerable road users (VRUs)								
Evaluation parameters	Converted bus		Remodelled e3W pax		Remodelled e3W cargo		New e3W design pax	
	Answer	Justification	Answer	Justification	Answer	Justification	Answer	Justification
Effect on road accidents involving vulnerable road users (VRUs)	No change	[1] [2] [4] [5] [7]	No change	[1] [3] [4] [6] [7]	No change	[1] [3] [4] [6] [7]	No change	[1] [3] [4] [6] [7]
SCORE (7-point scale in parenthesis)	**3** (4.00)		**3** (4.00)		**3** (4.00)		**3** (4.00)	
Evaluation parameters	New e3W design cargo		Converted e4W waste		Converted truck		New e-Shuttle van	
	Answer	Justification	Answer	Justification	Answer	Justification	Answer	Justification
Effect on road accidents involving vulnerable road users (VRUs)	No change	[1] [3] [4] [6] [7]	No change	[1] [2] [4] [5] [7]	No change	[1] [2] [4] [5] [7]	No change	[1] [2] [4] [5] [7]
SCORE (7-point scale in parenthesis)	**3** (4.00)		**3** (4.00)		**3** (4.00)		**3** (4.00)	

Notes		Interviewees
[1]	In Nepal, most of the accidents are due to driver's negligence rather than vehicle's failure. Drivability of EVs is usually better than this of the ICE-run vehicles.	[I.1]
[2]	The impacts caused by vehicle accidents involving buses, e-shuttle vans and trucks are higher as these vehicles usually run at higher speeds. *[Response discarded as irrelevant]*	[I.2]
[3]	E-3wheelers run at lower speeds and will have lower impact in case of accident. *[Response discarded as irrelevant]*	[I.2]
[4]	The impacts caused by a vehicle accident depend on mass and momentum. So there should be no significant changes for any vehicle type.	[I.3]
[5]	The parameters that matter the most here are the size and power of the vehicle. The e-shuttle van, bus and truck have more power and are likely prone for more damage to VRUs. *[Response discarded as irrelevant]*	[I.4]
[6]	The parameters that matter the most here are the size and power of the vehicle. The 3-wheelers run at lower speeds and, as such, are much safer. *[Response discarded as irrelevant]*	[I.4]
[7]	E-vehicles generate low intensity sound which is likely to cause more accidents.	[I.5]

4.2.5. 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):[13]

- 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.

[13] 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.

- 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.[14] 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 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 Table 4.14 below:

Table 4.14. Severity of charging accidents

	Potential Severity/Scale of Impact[15]
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:

[14] https://www.terrellhogan.com/electric-vehicle-battery-fire-risks/
[15] Ideally to be assessed by local experts and should consider the scale (e.g. potential number of affected people) and severity of impacts.

Table 4.15. Likelihood of occurence, charging accidents

	Likelihood of Occurrence[16]
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 Table 4.16 below:

Table 4.16. Hazard categories

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.

Example from Kathmandu

Table 4.17 below presents the evaluation of the KPI for the Kathmandu components. The scores in the table are identical to the star values that enter the evaluation framework directly.

Table 4.17. Impact on charging safety incidents, Kathmandu

E.9 Impact on charging safety incidents								
Demo component	**Electrical shock**		**Fire hazards**		**Power grid instability**		**Highest risk**	**SCORE**
	Occurrence [1]	**Severity** [2]	**Occurrence** [3]	**Severity** [4]	**Occurrence** [5]	**Severity** [6]		
Converted bus	2,20	3,00	1,40	3,60	3,00	1,60	6,60	**2**
Remodelled e3W pax	2,00	3,00	1,00	3,60	3,00	1,20	6,00	**3**
Remodelled e3W cargo	2,00	3,00	1,00	3,60	3,00	1,20	6,00	**3**
New e3W design pax	0,80	3,00	0,80	3,60	3,00	1,20	3,60	**3**
New e3W design cargo	0,80	3,00	0,80	3,60	3,00	1,20	3,60	**3**
Converted e4W waste	2,20	3,00	1,40	3,60	3,00	1,60	6,60	**2**
Converted truck	2,20	3,00	1,40	3,60	3,00	1,60	6,60	**2**
New e-Shuttle van	0,60	3,00	1,00	3,60	3,00	1,20	3,60	**3**

[16] The assessment of the likelihood of occurrence should consider the safety measures that are embedded in the project.

4.2.6. Effect on security incidents

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 scale in Table 4.18 is used:

Table 4.18. Risk impact scale

	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 (Table 4.19):

Table 4.19. Risk probability

	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 Table 4.20 below.

Table 4.20. Assessment matrix

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.

Example from Kathmandu

Table 4.21 below presents the evaluation of the KPI for the Kathmandu components. The scores in the table are identical to the star values that enter the evaluation framework directly.

Table 4.21. Impact on security incidents

E.10 Impact on security incidents										
Demo component	Infrastructure & operations [1]		Vehicles [2]		Transport of goods [3]		Transport of people [4]		Highest risk	SCORE [5]
	Occurrence	Severity	Occurrence	Severity	Occurrence	Severity	Occurrence	Severity		
Converted bus	1,67	3,00	2,00	3,33			3,67	3,67	13,44	3
Remodelled e3W pax	1,67	3,00	2,00	3,33			3,67	3,67	13,44	3
Remodelled e3W cargo	1,67	3,00	2,00	3,33	2,33	1,67			6,67	3
New e3W design pax	1,67	3,00	2,00	3,33			3,67	3,67	13,44	3
New e3W design cargo	1,67	3,00	2,00	3,33	2,33	1,67			6,67	3
Converted e4W waste	1,67	3,00	2,00	3,33	1,67	1,67			6,67	3
Converted truck	1,67	3,00	2,00	3,33	1,67	1,67			6,67	3
New e-Shuttle van	1,67	3,00	2,00	3,33			3,67	3,67	13,44	3
Notes										
[1]	Security incidents concerning infrastructure & operation relate to theft, vandalism, terrorism, or other unlawful activities. The experts consider exogenous factors such as the socio-economic conditions, political environment, and geographical aspects to be the main drives for this kind of challenges. This is the reason for giving identical scores to all demo components. Two experts assessed the likelihood of occurance as moderate (once per year) and one as low (less than once per 5 years). Severity was assessed as moderate by all three experts.									
[2]	Security incidents concerning vehicles relate to theft, vandalism, terrorism, or other unlawful activities. Once again, the experts decided to score all components in a uniform way. All three experts assessed the likelihood of occurance as moderate (once per year). Severity was assessed as moderate by two experts and high by one.									
[3]	Security incidents concerning transport of goods relate to theft, pilferage or damage to goods during transportation. For the 3-wheelers, two experts assessed the likelihood of occurance as moderate (once per year) and one as high (once per month). For the 4-wheelers, two experts assessed the likelihood of occurance as low (less than once per 5 years) and one as high (once per month). Expected impacts include financial losses due to stolen or damaged goods, disruptions to supply chains, and potential inconvenience to businesses and customers. Severity was assessed as low by two experts and minor by one for all cargo vehicles.									
[4]	Security incidents concerning transport of people relate to theft, robbery, assault, harassment, or other forms of violence against passengers/operators during service provision. Likelihood of occurence was assessed as very high (once per week or more frequently) by two experts, and high (once per month) by one expert for all passenger vehicles. Expected impacts include physical harm, psychological trauma, loss of personal belongings, disruption of transportation services, and negative effects on public confidence in the transport system. Severity was assessed as high by two experts and moderate by one for all passenger vehicles.									
[5]	Based on the highest risk, all passenger vehicles perform much worse than the cargo 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, scoring all components with 3.									

4.2.7. 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.

Example from Kathmandu

No effect is expected by the planned activities.

4.2.8. Quality of e-mobility services

The KPI is assessed using the questionnaire outlined in Table 4.22 below.

Table 4.22. Questionaire on the 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 Ease of driving (by professional drivers)	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 #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.

Example from Kathmandu

At the time of drafting this document, the service quality survey had not been undertaken.

5. Scaled-up project assessment

5.1. Wider economic indicators

5.1.1. 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.

5.1.2. 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.

5.1.3. 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.

Example from Kathmandu

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. In China, the previous 10-year plan aimed at creating 1.2 million jobs engaged in producing 1.67 million new EVs annually during the decade 2010–2020.

Three experts affiliated with car manufacturing and sales provided their views on the potential impact of EV manufacturing on job creation. To consider the effect of economies of scale, the interviewees were asked to consider the manufacturing of 35 units of each type of vehicle in the period 2023-2030. The responses received are summarised in Table 5.1, where also the net effect per unit of manufactured vehicle is presented. The scores in the table are identical to the star values that enter the evaluation framework directly.

Table 5.1. Effect on jobs, Kathmandu

F.4 Effect on jobs					
Demo component	Old solution	New jobs	Job losses	Net effect on jobs	Net effect on jobs
		(per 35 new vehicles) [1]			(per new vehicle)
Converted bus	Diesel bus	81,00	58,67	22,33	0,6381
Remodelled e3W pax	Existing Safa Tempo (pax)	34,00	20,00	14,00	0,4000
Remodelled e3W cargo	Petrol-driven pick-up truck	34,00	20,00	14,00	0,4000
New e3W design pax	Existing Safa Tempo (pax)	34,00	10,67	23,33	0,6667
New e3W design cargo	Petrol-driven pick-up truck	34,00	10,67	23,33	0,6667
Converted e4W waste	Petrol-driven 3-wheeler	34,00	10,67	23,33	0,6667
Converted truck	Petrol-driven pick-up truck	67,67	46,67	21,00	0,6000
New e-shuttle van	Open-type e-shuttle van	35,00	10,67	24,33	0,6952
Notes					
[1] The interviewees were asked to provide their estimates for a batch of 35 vehicles of each type.					

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 Table 5.2 below:

Table 5.2. Average monthly salaries of specialists

	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.

Example from Kathmandu

The same experts interviewed for job creation were asked to provide their estimates for the net positions of technically skilled employees that would be generated by the manufacturing and maintenance of 35 units of each vehicle type. Their responses are presented in Table 5.3. The last two columns of the table transform the net positions of all three specialties into EV technician equivalent ones for the set of 35 vehicles, as well as for a single unit.

Table 5.3. Effect on technical skills, Kathmandu

F.5 Effect on technical skills												
Demo component	Old solution	EV technicians			EV design engineers			IT analysts & other experts			EV technician equivalent [1]	
		New jobs	Job losses	Net add.	New jobs	Job losses	Net add.	New jobs	Job losses	Net add.	Net (35 veh.) [2]	Net/unit
Converted bus	Diesel bus	12,67	3,00	9,67	5,00	0,00	5,00	4,33	0,00	4,33	22,63	0,6466
Remodelled e3W pax	Existing Safa Tempo (pax)	7,00	2,33	4,67	4,00	0,00	4,00	4,00	0,00	4,00	15,91	0,4545
Remodelled e3W cargo	Petrol-driven pick-up truck	7,00	2,33	4,67	4,00	0,00	4,00	4,00	0,00	4,00	15,91	0,4545
New e3W design pax	Existing Safa Tempo (pax)	11,00	2,67	8,33	7,67	0,00	7,67	6,00	0,00	6,00	27,16	0,7760
New e3W design cargo	Petrol-driven pick-up truck	11,00	2,67	8,33	7,67	0,00	7,67	5,67	0,00	5,67	26,62	0,7605
Converted e4W waste	Petrol-driven 3-wheeler	11,00	2,67	8,33	7,67	0,00	7,67	5,67	0,00	5,67	26,62	0,7605
Converted truck	Petrol-driven pick-up truck	15,00	4,00	11,00	5,00	0,00	5,00	5,00	0,00	5,00	25,05	0,7157
New e-shuttle van	Open-type e-shuttle van	13,67	3,00	10,67	7,67	0,00	7,67	5,67	0,00	5,67	28,95	0,8271
Notes												
[1]	Based on their mean salaries in Nepal (23/1/2024), 1 EV design engineer accounts for 1,18 EV technicians, and 1 IT analyst accounts for 1,63 EV technicians.											
[2]	The interviewees were asked to provide their estimates for a batch of 35 vehicles of each type.											

5.2. Example on scaled-up project assessment from Kathmandu

The following describes the stages of performing a scaled-up assessment using the Kathmandu demonstration activities for illustration. The process includes setting up a baseline scenario, KPIs, the project design, optimization results, and finally the proposed scaled-up project.

5.2.1. Baseline scenario

The baseline scenario describes the situation in the project area as it would have developed in the absence of the investigated project and is used as the basis against which the impacts of the studied intervention are assessed. More specifically, the performance of the scaled-up project in relation to CO_2, NOx and $PM_{2.5}$ emissions is assessed against the cumulative volume of the respective emissions in the Kathmandu valley over the period 2024-2030. This section aims at estimating these emission volumes.

Initially, the eMOB calculator was selected for this purpose. However, due to its current beta state and consequent limited functionality, it cannot be used as planned. Instead, the Future Mobility Calculator (FMC) has been chosen for its established reliability and comprehensive features. FMC, an Excel-based tool developed by the World Resources Institute and Siemens in collaboration with the Coalition for Urban Transitions,[17] is primarily designed to aid cities in planning for the electrification of urban transportation systems. It concentrates on the adoption of EVs and the necessary infrastructure for urban mobility. The tool projects scenarios for EV adoption in 2030 and 2050, while primarily detailing the potential emissions (CO_2, NOx, $PM_{2.5}$) over the entire time horizon, alongside outlining the required infrastructure and its associated costs.

As seen in Figure 5.1, FMC is structured into three primary modules: data input (including initial data input – used for default values, city mobility and charging), calculations (covering mobility, charging and emissions), and results. The tool's interface is transparent, allowing users to integrate their own data for customisation.

[17] https://urbantransitions.global/en/publication/future-mobility-calculator-an-electric-mobility-infrastructure-tool/

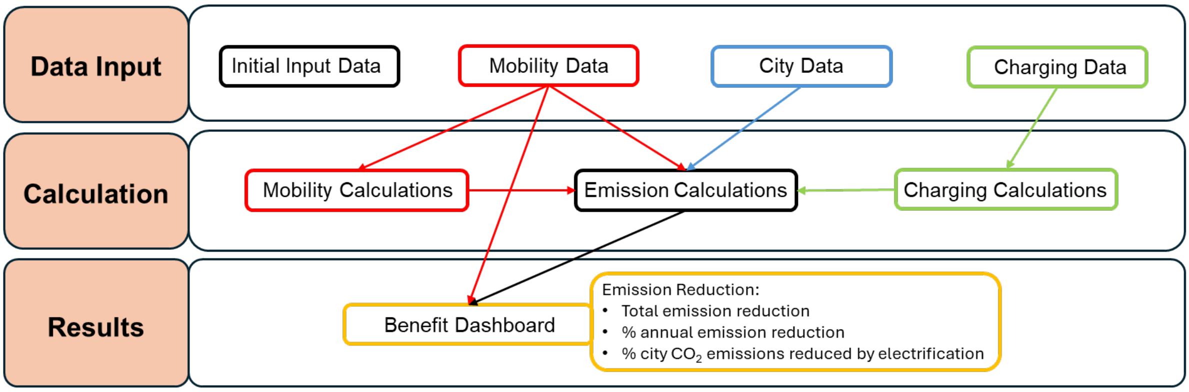

Figure 5.1. FMC components and functionality

Vehicle stock and emission factors

Among the administrative districts for which vehicle registration data is published, the Bagmati Province is the closest one to the Kathmandu valley. The vehicle types that are relevant for this analysis are minibuses, , 3-wheelers, and pick-up trucks (for the remaining demo vehicles). The total number of vehicles for 2022, as shown in Table 5.4, reflect the official statistics for the selected vehicle types. The 174 electric microbuses is an estimate of DoTM for the entire country (assuming that all of them are registered in the Bagmati Province). In relation to 3Ws, local press[18] estimates about 1,000 non-diesel vehicles, out of which about 700 are Safa Tempos.

Table 5.4. Relevant vehicle stock

Vehicle types		Vehicle stock (Bagmati Province)			Annual mileage (km/year)				Lifespan (years)	Fuel efficiency (km/lt)	Emission factors (gr/km)		
		2022	2030	2050	Km/trip	Trips/day	Days/year	Mileage (km/year)			CO2 (WtW)	NOx	PM2.5
Mini buses	Diesel	9.284	11.618	18.545	32	4	326	41.728	20	4,5	678,04	9,02	2,34
	Electric	0	179	2.927	32	4	326	41.728	20		0,00	0,00	0,00
	Total	9.284	11.797	21.472									
Micro buses	Diesel	5.262	4.588	3.376	10	10	320	32.000	20	6,2	471,46	2,21	0,76
	Electric	174	1.037	2.752	10	10	320	32.000	20		0,00	0,00	0,00
	Total	5.436	5.625	6.127									
3-wheelers	Diesel	4.195	4.063	3.750	13	9	330	38.610	20	12,5	156,22	1,47	1,20
	Gas	300	0	0	13	9	330	38.610	20	20,2	81,78	0,04	0,13
	Electric	700	0	0	13	9	330	38.610	30		0,00	0,00	0,00
	Total	5.195	4.063	3.750									
Pick-up trucks	Diesel	39.429	57.635	60.936	20	3,5	330	23.100	20	12,0	250,00	1,15	1,58
	Electric	0	620	10.145	20	3,5	330	23.100	20		0,00	0,00	0,00
	Total	39.429	58.255	71.082									

The total number of minibuses for 2030 and 2050 is calculated based on the 2022 fleet and the compound annual growth rate (CAGR) estimated using the available official statistics for the period 2018-2022 (3.04%). Against the very ambitious SDG targets for the shares of EVs in PT (50% by 2030), it was assumed that 179 minibuses will be electric by 2030 (30 initial vehicles growing at 25% annually), the number reaching 2,927 by 2050 (at a CAGR of 15%).

[18] https://kathmandupost.com/valley/2020/08/01/tempo-drivers-are-driven-to-despair-as-not-many-are-using-these-three-wheelers-over-covid-19-fears

A CARG of 0.43%, estimated over the 2018-2022 period, is applied to the 2022 microbus fleet to reach the 2030/2050 projections. The electric microbuses are assumed to grow by 25% per year until 2030 and 5% thereafter.

According to the 2018-2022 statistics, the 3-wheeler fleet (no distinction between passenger and cargo use) is shrinking by 0,40% per year. This trend is kept unchanged for the 2030/2050 projections. As per Bagmati Province's periodic Plan for 2019-2023, the gas 3Ws will be banned by 2028. Safa Tempos will also be retired once their 30-year license expires by 2030.

The 2018-2022 data indicate a CARG of 6.96%. A more moderate 5% growth rate has been assumed for the period until 2030, followed by an 1% rate for the 2030-2050 period. Similarly to the minibuses, 620 pick-up trucks are expected to be electric by 2030 (130 initial vehicles growing at 25% annually), the number reaching 10,145 by 2050 (at a CAGR of 15%).

The lifespan of all vehicles is assumed to be 20 years, apart from Safa Tempos, for which a special license extension to 30 years has been officially issued.

Based on these inputs, the baseline scenario CO_2 (WtW), NOx and $PM_{2.5}$ emissions, as computed by FMC, are depicted in Figure 5.2 below. The savings in emissions escalate over time with the expansion of the electric fleet, highlighting its positive impact. However, a steady increase in emissions, even until 2050, is observed due to the continuous growth in the number of ICE vehicles. Although the growth rate of ICE vehicles declines over time as they are gradually replaced by EVs, there is still an increase in their numbers. This means that the growth rates for EVs assumed in the input data need to be revised if emissions are to be stabilised and reduced well before 2050. A 25% annual growth rate for EVs has been assumed for the period until 2030. Considering the realities in the country, a higher rate for these early years appears excessively optimistic. On the contrary, the CARG used for the 2030-2050 period should be revised upwards. Given, however, that the assessment period of the present analysis ends with 2030, any adjustments in the EV sales afterwards will have no effect on the analysis results. The cumulative emissions of the baseline scenario for the period 2024-2030 that enters the assessment of the scaled-up scenario appear in Table 5.4.

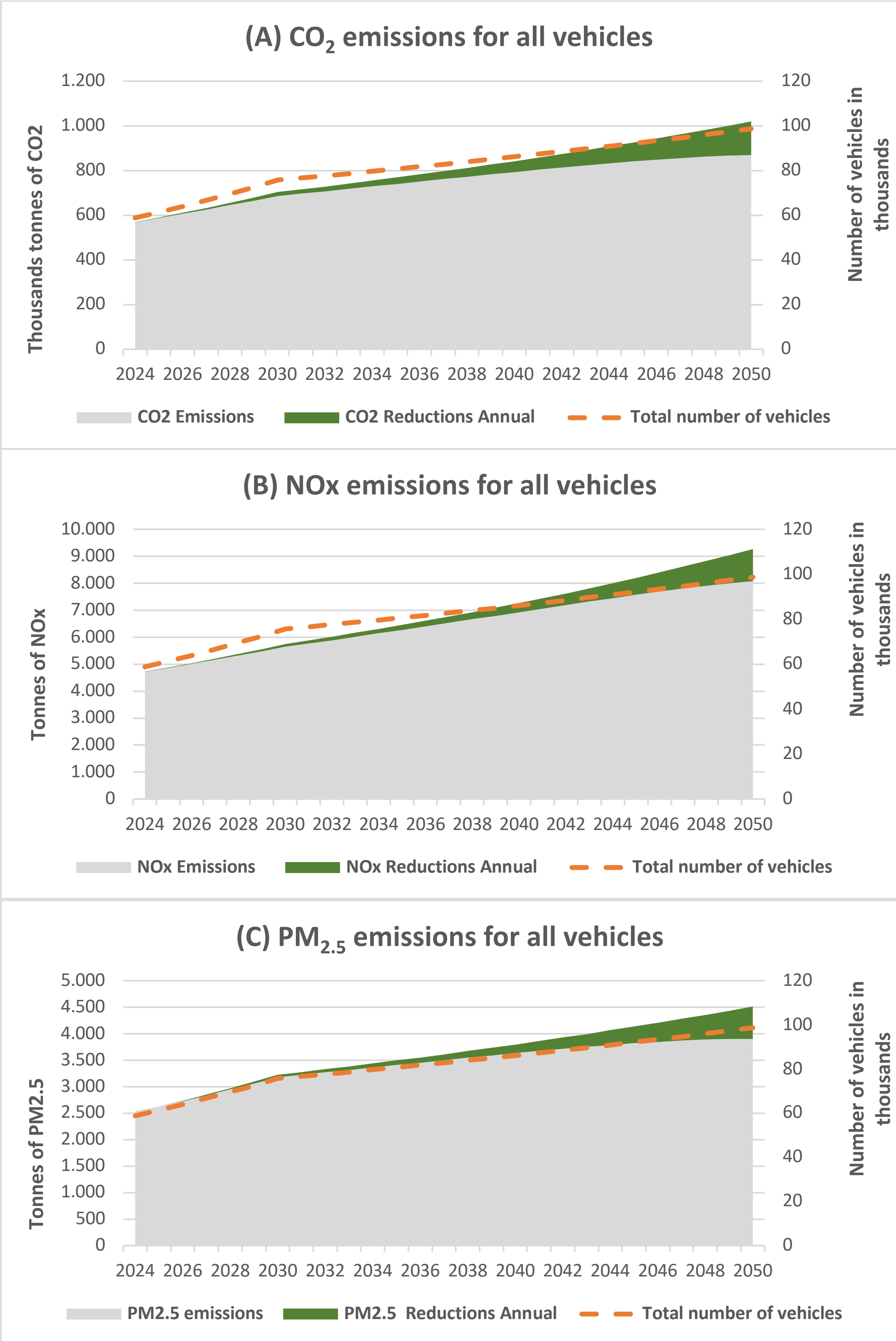

Figure 5.2. Baseline scenario emissions

5.2.2. *KPIs for assessing the scaled-up project*

All KPIs enter the assessment of the scaled-up project. The indicators concerning the effect of the project on the wider economy should, thus, be added to those. These additional indicators relate to the effect on budget, external trade, and employment. Unfortunately, the efforts made by the city team to gather data on the budget of relevant institutions (municipalities of the Kathmandu valley) available for the procurement of vehicles, proved fruitless and the corresponding KPI had to be dropped from the analysis. Lack of data also lead to abandoning the KPI on the effect on 'other imports,' restricting external trade consideration to merely fossil fuel imports. When viewed in isolation, however, this indicator exhibits a great deal of overlap with the effect on GHG emissions, which is not allowed by the MECE (mutually exclusive and collectively exhaustive) principle of KPI trees. As such, both indicators on external trade were finally excluded, and the wider economy effects were reduced to impacts on employment through job creation and technical skill requirements, which are presented in Section 5.1.

5.2.3. *Scaled-up project design*

The baseline scenario and the KPIs on employment complete the basic input for designing the scaled-up project. Before presenting some methodological issues concerning the optimisation process itself, it is necessary to define the boundaries (scope) of the alternative designs to be assessed.

Firstly, to ensure that the necessary input is available, the scaled-up project should consist of an unspecified (integer) number of units for the eight types of vehicles examined in the Kathmandu demo. Other vehicle types are excluded.

Secondly, the optimisation process should relate to a specific institution (project owner), who will undertake the necessary investments. A closer look at the eight vehicles of the demo, reveals that five of them (the four e3W components and the converted truck) are vehicles owned and operated by private interests, either investors or operators/drivers. All these vehicles are financially sound with pre-tax IRR values ranging from 30.58% (newly designed e3wheeler – passenger service) to 87.93% (newly designed e3wheeler – cargo service) at constant 2022 prices.[19] Thus, no investments are required by the public sector for these vehicles, other than supporting activities such as 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. The remaining vehicles either fall directly into the public sector sphere as they do not earn revenues (waste collector & shuttle van) or if they do, they are operated by semi-public structures such as the Sajha Yatayat (converted bus). For simplicity purposes, it is assumed that a public entity such as the Lalitpur municipality will be the owner for a scaled-up project consisting of these three types of vehicles.

Thirdly, the project owner has to define the available budget for this activity. A budget line of € 2 million is assumed for this purpose.

Fourthly, the project owner has to define the lower and upper limits of the respective fleets depending on their function. To ensure economies of scale, a lower limit of 10 units has

[19] It is worth mentioning that this result is achieved after several assessment iterations optimising the design and operational profile of the vehicles.

been assumed for all three vehicle types, as long as any of them is selected in the composition of the scaled-up project fleet. Upper limits have been imposed only for the waste collectors and shuttle vans (30 units for each type), as the municipality will probably not need more of these vehicles. The converted buses are left unconstrained from above.

Methodological aspects

The optimisation objective function is of the following form:

$$\max_{\alpha \epsilon \Omega} V(x) = \sum_{i=1}^{M} w_i \, v_i(x)$$

where:

x = a 3-dimensional decision vector [x_1, x_2, x_3] indicating the units of each vehicle type that comprise a specific alternative solution

M = the number of KPIs participating in the assessment

V(x) = the overall rating of alternative x

$v_i(x)$ = the score (performance) of alternative x against KPI i $(i = 1, \ldots, M)$

w_i = the weight (relative importance) that the decision makers assign to KPI i
$[0 \leq w_i \leq 1]$ and $\sum_{i=1}^{m} w_i = 1$

Ω = the feasible region

Some of the KPI scores, however, contain metrics such as the share of vehicle type x_j in total investment, making the objective function non-linear. Traditional linear solvers cannot be used in such cases requiring the use of a metaheuristic. Metaheuristics are advanced computational algorithms that operate by intelligently exploring the search space through mechanisms that balance exploration (investigating new, unvisited areas) and exploitation (deepening the search around promising areas). This dual approach enables them to efficiently navigate through complex problem landscapes to identify high-quality solutions, often close to the global optimum.

Three different metaheuristics are selected for this particular application: (i) Simulated Annealing (SA), (ii) Evolutionary Algorithm (EA), and (iii) Grey Wolf Optimiser (GWO). Each of these methods, briefly explained below, has its strengths and mechanisms for exploring the solution space and converging towards an optimal or near-optimal solution. All metaheuristics for this application have been executed using the Julia programming language.

Simulated Annealing (SA)

Simulated Annealing is inspired by the annealing process in metallurgy. It is a physical process used to alter the properties of metals: the material is heated to a high temperature and then allowed to cool slowly. The slow cooling process is crucial as it lets the atoms within the material rearrange themselves into a state of minimum energy, leading to a more stable and orderly structure. This process helps in reducing defects, increasing ductility, and relieving internal stresses. The idea of this metaheuristic is to find a low-energy state of a system that corresponds to an optimal or near-optimal solution to a given problem. In the context of optimisation, the ‘energy’ of the system is analogous to the objective function that needs to be maximised and the ‘state’ of the system represents a potential solution.

The algorithm starts by initialising the process with a random solution to the problem, which is then iteratively improved upon. At each step, the SA heuristic considers moving from the current solution to a neighbour solution. In our case, a neighbour solution is found by selecting randomly a component (type of vehicles) of the current solution and add to the value component (number of vehicles) a random number between -10 and 10. The decision to move to this new solution is made based on a comparison of the two solutions' objective function values. If the adjacent solution is better, this becomes the new arrangement of the solution, which is then explored in the next iteration. By only accepting the best solutions, the algorithm could lead to a local maximum. So, to avoid this, an acceptance criterion is also defined based on the current temperature of the system. Early in the algorithm, when the temperature is high, there is a higher likelihood of accepting worse solutions, allowing the algorithm to explore the solution space more freely and potentially escape local maxima. As the temperature decreases, the algorithm becomes more conservative, preferring only moves that improve the solution or that represent slight deteriorations, thereby focusing the search on regions of the solution space where a near-optimal solution is likely to be found.

Box 1: Pseudo code of the SA algorithm

1. Initialise a feasible solution to the problem.
2. Initialise the temperature of the system.
3. Initialise the number of iterations.
4. **WHILE** the number of iterations is less than the maximum number of iterations, **DO:**
    a. Generate a neighbour solution based on the current solution.
    b. **IF** the neighbour solution is better than the current solution (in terms of KPIs stars) **OR IF** the acceptance criterion based on the temperature of the system is true, **THEN:**
        i. The neighbour solution becomes the current solution.
    c. **END IF**
    d. Update the temperature of the system.
    e. Update the number of iterations.
5. **END WHILE**

Evolutionary Algorithm (EA)

The Evolutionary Algorithm is based on the principles of Darwinian natural selection and genetic mechanisms observed in biological evolution. Its core concept is to mimic the evolutionary process of natural selection where the fittest individuals are more likely to survive and reproduce. The main biological inspirations are the natural selection (weak species cease to exist through natural selection, whereas strong ones can pass their genes to future generations), genetics and inheritance (biological organisms inherit traits from their parents through genes), and mutations of the children's genes (variation of the genes, represented as random changes, enabling the exploration of the solution space and the possibility of discovering more optimal solutions). These changes may provide additional advantages and may be carried onto the next generation. These mutations often help ensure that the solution does not get stuck on a local extreme point. Over time, fitter solutions will dominate the population until the solution eventually converges on a single optimal solution.

The process starts with the initial population P, consisting of a given number of individuals (feasible solutions). This given number of individuals is a parameter for the algorithm, and must be determined, so that the metaheuristic is as efficient as possible. The creation of the population is done to ensure a diverse gene pool in the different iterations. After this, two individuals are selected to become the parents of the new generation. This is done by giving a probability of being picked to everyone, depending on their score. The better the score, the more likely an individual will be selected. The next step consists of generating two children by crossing over the genes of the parents. To create diversity in the population, a mutation on the genes of the children is carried out. For each child, this is done by selecting randomly one of their components (type of vehicles) and add to the component value (number of vehicles) a random number between -10 and 10. Finally, two individuals from the population are selected to be replaced with the two new children. This is done by giving a probability of being picked to everyone, depending on their score. The worse the score, the more likely an individual will be selected. These steps are repeated until reaching the maximum number of iterations.

Box 2: Pseudo code of the EA

1. Initialise the population with a given number of individuals (feasible solutions).
2. Initialise the number of iterations.
3. **WHILE** the number of iterations is less than the maximum number of iterations, **DO:**
    a. Select randomly two individuals in the population (parents).
    b. Generate two children by crossing over the genes (components) of the parents.
    c. Create a mutation on the genes (components) of the children.
    d. Select randomly two individuals in the population and replace them with the new solutions generated.
    e. Update the number of iterations.
4. **END WHILE**
5. Identify the best individual.

Grey Wolf Optimiser (GWO)

This is an algorithm inspired by the social hierarchy and hunting behaviour of grey wolves in nature. These animals are known for their well-organised social structure and highly cooperative hunting tactics. The social structure of a grey wolf pack is primarily hierarchical, with four levels of rank: Alpha, Beta, Delta, and Omega. The Alpha wolf is the leader of the pack, and it represents the best solution found so far. The Beta wolf is the second in command, and it represents the second-best solution found so far. The Delta wolf is the third in command, and it represents the third-best solution found so far. And finally, the Omega wolves represent the bottom of the hierarchy and tend to follow the orders of the higher-ranked wolves. In the algorithm, Omega wolves follow the Alpha, Beta, and Delta wolves, simulating the exploration of the search space. The hunting strategy of grey wolves is another critical aspect that the GWO algorithm simulates. This strategy typically involves three steps: searching for prey, encircling, and harassing the prey, and finally attacking it. In the algorithm, these steps are mimicked to adjust the positions of potential solutions in the search space, effectively moving towards the optimal solution over iterations.

The process starts by initialising the position of the initial population of wolves, consisting of a given number of individuals (feasible solutions). In the case of the project, the position of the wolves is represented by the number of each type of vehicles. Then, the score of each individual is calculated, so that it is possible to find out who are the Alpha, Beta and Delta wolves. This step represents the search for prey by the group of wolves. After this, the Omega wolves start to encircle the prey. It is done by updating their position, so that they come closer to the higher-ranked wolves. For a given Omega wolf, the position update is calculated by considering its initial position, and the positions of the Alpha, Beta and Delta wolves. This process is repeated until it reaches the maximum number of iterations. At the end of the algorithm, all the wolves get to the same position (same feasible solution), representing the attack against the prey.

Box 3: Pseudo code of the GWO algorithm

1. Initialise the position of the population with a given number of individuals (feasible solutions).
2. Initialise the number of iterations.
3. **WHILE** the number of iterations is less than the maximum number of iterations, **DO:**
    a. Calculate the score of each individual.
    b. Assign the individual with the best score as the Alpha wolf.
    c. Assign the individual with the second-best score as the Beta wolf.
    d. Assign the individual with the third-best score as the Delta wolf.
    e. Update the position of the Omega wolves (remaining of the population) to make it closer to the position of the Alpha, Beta, and Delta wolves.
    f. Update the number of iterations.
4. **END WHILE**

NB: The position of the wolves can be seen as the value of the different components of the solution.

5.2.4. Optimisation results

Table 5.6 summarises the vehicle-specific input that enters the optimisation model. A total of 23 KPIs (out of the original set of 34) enter the scaled-up assessment. It is worth noting, however, that 7 of them (B1, B3, E6, E7, E8, E10, E18) will not have an effect in the outcome as identical scores are given to all three vehicles.

To evaluate the effectiveness and efficiency of the three metaheuristic algorithms mentioned above, each algorithm is executed 100 times. Each time, the highest scaled-up star rating and the corresponding fleet configuration are reported. The effectiveness of the metaheuristics is assessed based on the frequency with which the highest star rating is achieved out of the 100 repetitions. Efficiency is gauged by computing the average duration required to execute the metaheuristic algorithms.

Table 5.6. Input for the optimisation model

Code	KPIs participating in the assessment	KPI weight		Converted bus	Waste Collector	E-shuttle van
		Absolute	Normalised	KPI score (or attribute value that needs to be transformed into a star value thru a value function)		
	Required investment (EURO per unit)			**46.235**	**14.465**	**17.820**
A1.	Financial viability	0,122452	0,151963	3	4	5
A2.	Availability of financial resources	0,111906	0,138875	3	2	3
B1.	Coherence with national plans	0,058573	0,072689	5	5	5
B2.	Alignment with legislation	0,054022	0,067041	2	2	3
B3.	Ease of implementation	0,063906	0,079307	3	3	3
C1.	Effect on GHG emissions (tonnes/year/unit)	0,131929	0,163724	-15,14	-3,42	-15,09
D1.	Effect on NOx emissions (kg/year/unit)	0,028315	0,035140	-201,30	-15,61	-70,75
D2.	Effect on PM2.5 emissions (kg/year/unit)	0,035386	0,043915	-52,00	-5,35	-24,19
D3.	Effect on noise	0,042560	0,052817	5	4	3
D4.	Effect on environmental resources	0,048381	0,060041	5	5	1
E6.	Effect on major accidents	0,006757	0,008385	4	4	4
E7.	Effect on minor accidents	0,004625	0,005740	4	4	4
E8.	Effect on vulnerable road users	0,004662	0,005786	3	3	3
E9.	Effect on charging safety incidents	0,017880	0,022189	2	2	3
E10.	Effect on security incidents	0,012324	0,015295	3	3	3
E12.	Suitability for adverse weather	0,002225	0,002761	4	5	5
E13.	Perceived comfort	0,002562	0,003179	4	4	3
E14.	Perceived drivability (prof. drivers)	0,002168	0,002690	4	4	3
E16.	Perceived chargeability	0,003002	0,003725	2	2	3
E17.	Perceived safety	0,002739	0,003400	4	4	3
E18.	Perceived personal security	0,002306	0,002862	4	4	4
F4.	Effect on jobs (net jobs per unit produced)	0,026421	0,032789	0,6381	0,6667	0,6952
F5.	Effect on technical skills (net EV technician equivalent positions per unit produced)	0,020699	0,025688	0,6466	0,7605	0,8271
	Total	0,805799	1,000000			
	Provisional scoring by the Kathmandu city team pending completion of ex post assessment					

The optimisation results appear in Table 5.7. With an overall rating of 3.29556, a fleet composed of 25 buses, 20 waste collectors and 30 shuttle vans is the best performing solution. All three algorithms have identified the same best performing solution. It is worth noting that due to the utilisation of metaheuristic algorithms, the highest star rating obtained may not represent the optimal solution in theory. Nevertheless, given the project's scale and the constrained budget, it is feasible to enumerate all viable solutions in an Excel spreadsheet and manually calculate the optimal star rating. Through this method, it has been confirmed that the optimal star rating is indeed 3.29556, achieved with a configuration of 25 buses, 20 waste collectors, and 30 shuttle vans.

Table 5.7. Optimisation results (Scenario A)

	Simulated annealing	Evolutionary algorithm	Grey wolf optimiser
Best star rating found	3.29556	3.29556	3.29556
Best fleet found	[bus, waste, van] [25, 20, 30]	[bus, waste, van] [25, 20, 30]	[bus, waste, van] [25, 20, 30]
Effectiveness: Frequency of occurrence of best star rating	7 /100	6 / 100	91 / 100
Efficiency: Average duration of computing time	28.70 seconds	1.89 seconds	0.13 seconds

Table 5.8. Estimated effect of the scaled-up project on emissions (Scenario A)

Type of emission	Baseline scenario Cumulative emissions (tonnes)		Scaled-up scenario Cumulative emissions (tonnes)		Percentage change between scenarios	
	2024-2030	2024-2050	2024-2030	2024-2050	2024-2030	2024-2050
CO_2 (WtW)	4,380,831	20,241,843	4,362,914	19,836,002	-0.41%	-2.00%
NOx	36,217	175,685	36,053	171,334	-0.45%	-2.48%
$PM_{2.5}$	19,887	92,321	19,833	90,894	-0.27%	-1.55%

The effect of the scaled-up project on emissions is obtained by channelling the optimisation results into the FMC. Table 5.8 presents the reduction in the cumulative emissions of the periods 2024-2030 and 2024-2050 resulting from the scaled-up project. The annual emissions are also depicted in Figure 5.3. It is interesting to observe that emissions now peak during the period and start dropping towards the end of the 2040s.

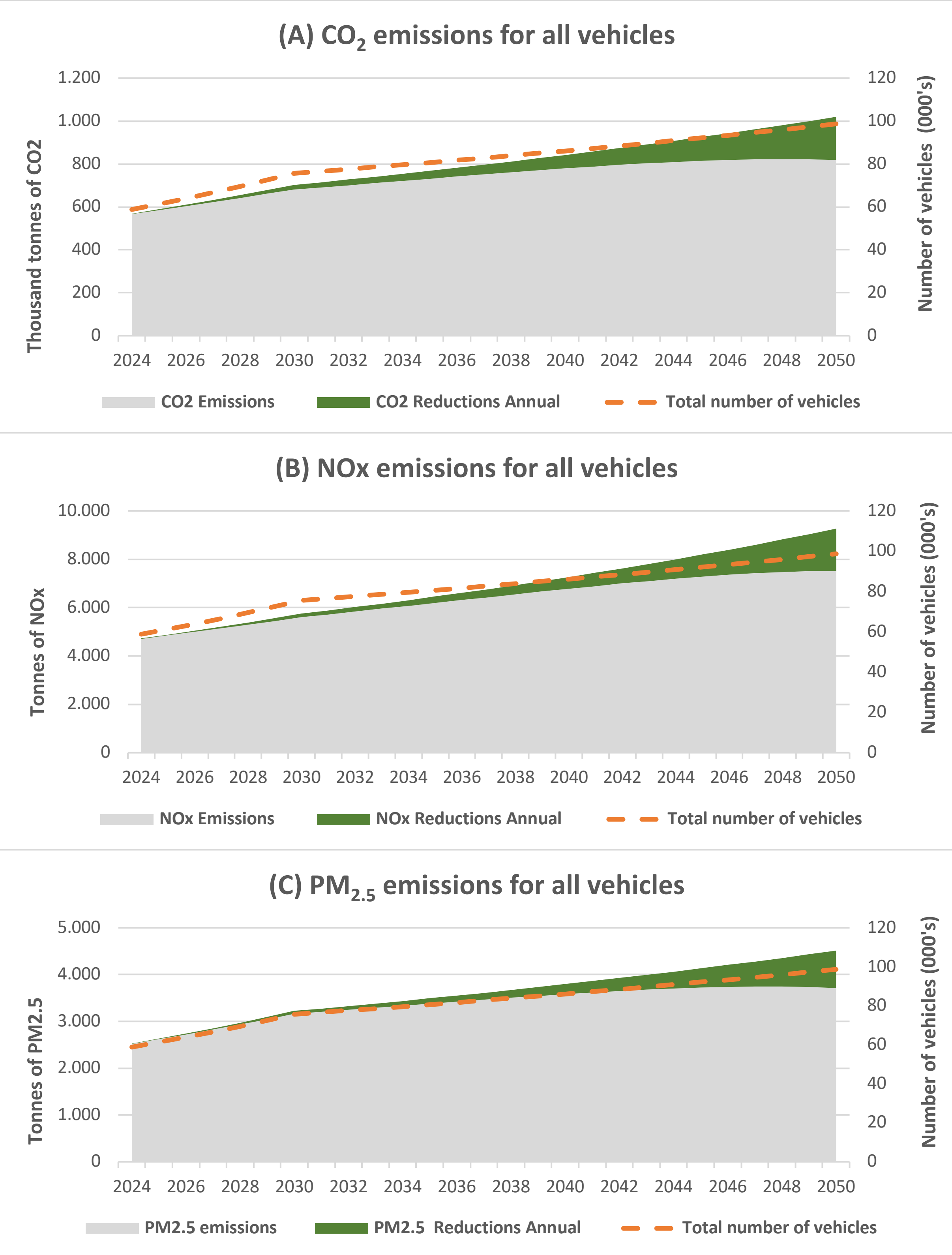

Figure 5.3. Effect of the scaled-up project on emissions (Scenario A)

It is possible that Lalitpur municipality might find the investment in 30 shuttle vans excessive, particularly considering that these vehicles earn no revenues and are targeted to tourists, who will likely be willing to pay the fare for a taxi or hotel van to visit the historic sites. In view of this possibility, it was decided to run a second scenario of the scaled-up project, excluding the e-shuttle vans altogether. Under the same budget constraints, the optimal solution now consists of 40 buses and 10 waste collectors (Table 5.9).

For both scenarios, Tables 5.7 and 5.9 illustrate that the Grey Wolf Optimiser emerges as the best metaheuristic in this specific application, outperforming the others in terms of both effectiveness and efficiency.

The metaheuristic algorithms have been run on the same computer. The specifications of this computer are the following:

- Device name: DTU-CZC6268CHW
- Full device name: DTU-CZC6268CHW.win.dtu.dk
- Processor: Intel(R) Core(TM) i7-6700T CPU @ 2.80GHz   2.81 GHz
- Installed RAM: 16,0 GB (15,9 GB usable)
- Device ID: FC2C3B50-2218-4901-B0D9-3C622AD9CBFB
- Product ID: 00329-00000-00003-AA123
- System type: 64-bit operating system, x64-based processor

Table 5.9. Optimisation results (Scenario B)

	Simulated annealing	Evolutionary algorithm	Grey wolf optimiser
Best star rating found	3.25346	3.25346	3.25346
Best fleet found	[bus, waste] [40, 10]	[bus, waste] [40, 10]	[bus, waste] [40, 10]
Effectiveness: Frequency of occurrence of best star rating	53 /100	89 / 100	100 / 100
Efficiency: Average duration of computing time	15.78 seconds	1.15 seconds	0.10 seconds

5.2.5. *Suggested scaled-up project*

Following discussions with the stakeholders during a workshop that took place in Kathmandu on 24 April 2024, it was confirmed that Scenario B would be preferable for the Lalitpur municipality. As such, the suggested scaled-up project could look like:

● Conversion of 40 diesel buses	2.000.000 (= € 50.000 x 40)
● Conversion of 10 mini trucks to waste collectors	150.000 (= € 15.000 x 10)
● Activities promoting private investments in e3Ws & converted pick-up trucks	200.000 (lump sum)
● Project management, etc.	150.000 (lump sum)
● Contingencies	100.000 (lump sum)
Total (€)	**2.600.000**

The activities supporting investments by the private sector (in the four remodelled and newly designed e3Ws for passenger and cargo use, and the converted pick-up truck) should include:

- Support and monitor the continuous operation of the prototypes for at least six months to verify their technical and financial viability
- Present the financial results to commercial banks (with the intervention of international donors, if needed) to increase their awareness and possibly develop a fast-track loan offering scheme (in all these cases the initial investment is lower than 2 million NPR ≈ € 15.000).
- Undertake an awareness campaign targeting potential investors and operators

In relation to the bus and waste collector fleets, the following activities are suggested:

- Support and monitor the continuous operation of the prototypes for at least six months to verify their technical and financial viability
- Discuss with the relevant authorities the prospect of engaging in developing a fleet of such vehicles. For each one of these vehicles, the production batch cannot be lower than 10 units of each type in an effort to achieve economies of scale
- Identify potential local manufacturers interested in such a contract and verify findings of the performed financial assessment
- Investigate possibility of obtaining support from international donors
- Project management

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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 generated 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 2.1.

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 2.1) 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 2.1, '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.

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.

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. 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.

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).

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