D1.6 IMPACT ASSESSMENT RESULTS

VOLUME 4: KATHMANDU, NEPAL

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

PROJECT PARTNERS

ABOUT

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

TITLE

SOLUTIONSplus Impact Assessment Results

AUTHORS

George Panagakos, DTU
Shritu Shrestha, WI
Abhisek Karki, UEMI
Bhupendra Das, CAA
Bijay Thapa, CAA
Shankar Sharma, CAA
Bhushan Tuladhar, Sajha Yatayat
Janak Risal, Sajha Yatayat
Gaurab Raj, Sajha Yatayat

REVIEWERS

Michael Barfod, DTU
Subash Dhar, UNEP CCC
Oliver Lah, UEMI

DISCLAIMER

The views expressed in this publication are the sole responsibility of the authors named and do not necessarily reflect the views of the European Commission.

LAYOUT

Yasin Imran Rony, WI

PICTURES

All the pictures are provided by the SOL+ partners

June, 2024

APRIL 2024

DOCUMENT IDENTIFICATION			
STATUS	Final	DUE DATE	30 April 2024
VERSION	v2.0	SUBMISSION DATE	15 June 2024

DELIVERABLE NUMBER	D1.6 – Volume 4
DELIVERABLE NAME	Impact assessment results: Kathmandu, Nepal
WORK PACKAGE NUMBER	WP1
DELIVERY DUE DATE	30 April 2024
ACTUAL DATE OF SUBMISSION	15 June 2024 (v1.0 was submitted on 30 April 2024)
DISSEMINATION LEVEL	PU
LEAD BENEFICIARY	DTU
BENEFICIARIES	WI, CAA, UEMI
RESPONSIBLE SCIENTIST / ADMINISTRATOR	George Panagakos (DTU), Shritu Shrestha (WI), Abhisek Karki (UEMI), Bhupendra Das (CAA), Bijay Thapa (CAA), Shankar Sharma (CAA), Bhushan Tuladhar (Sajha Yatayat), Janak Risal (Sajha Yatayat), and Gaurab Raj (Sajha Yatayat)
ESTIMATED EFFORT (PERSON-MONTH)	
INTERNAL REVIEWER	Michael Barfod (DTU), Subash Dhar (UNEP CCC), Oliver Lah (UEMI)

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

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

EXECUTIVE SUMMARY

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

ASSESSMENT OF THE KATHMANDU DEMONSTRATION PROJECT MOTIVATION AND OBJECTIVES

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

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

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

USER NEEDS ANALYSIS

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

STAKEHOLDER PRIORITIES

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

FINANCIAL VIABILITY

The financial results are promising, with all vehicles achieving top score, except for the converted bus and the waste collector (with a score of 3 and 4 respectively in an 1-5 scale). For the six revenue-earning components, IRR ranges from 14,86% (converted bus) to 87,53% (new e3W design cargo). Both non-revenue-earning components exhibit significant reductions in the CER values, although care should be taken to verify these results in practice, as they are very sensitive to the actual transport work performed (volume of waste collected and passengers carried respectively).

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

AVAILABILITY OF FINANCIAL RESOURCES

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

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

INSTITUTIONAL ISSUES

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

CLIMATE CHANGE AND ENVIRONMENTAL ASPECTS

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

ROAD SAFETY

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

CHARGING SAFETY

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

SECURITY ISSUES

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

EFFECT ON EMPLOYMENT

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

SCALED-UP PROJECT

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

PREFEASIBILITY OF A MAAS APPLICATION

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

THE ASSESSMENT METHODOLOGY

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

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

a. At the first stakeholder workshop, the following three KPIs were considered irrelevant for the Kathmandu demo and excluded from the value function development:

- Effect on accessibility – passengers (E1)
- Effect on well-being through active travelling (E11)
- Effect on drivability as perceived by end users (E15)

a. Five more KPIs turned out to be irrelevant after obtaining information from the end users, drivers, and experts:

- Effect on accessibility – freight (E2)
- Effect on affordability (E3)
- Effect on travel time – passengers (E4)
- Effect on travel time – freight (E5)
- Effect on transhipment quality (E19)

a. Another two KPIs were dropped due to difficulties in obtaining the necessary data:

- Effect on budget (F1)
- Effect on other imports (F3)

a. One more KPI was finally dropped due to a great deal of overlap with the emission-related indicators, when viewed outside the external trade context:

- Effect on fossil fuel imports (F2)

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

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

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

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

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

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

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

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

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

CONTENTS

ABBREVIATIONS

ADB	Asian Development Bank
CAGR	Compound annual growth rate
CEN	Clean Energy Nepal
CER	Cost effectiveness ratio
CSE	Centre for Science and Environment
DoTM	Department of Transport Management
EA	Evolutionary algorithm (in the context of metaheuristics)
eMOB	e-mobility calculator (of UNEP)
EV	Electric vehicle
FMC	Future Mobility Calculator
FNNTE	Federation of Nepal National Transport Entrepreneurs
GDP	Gross domestic product
GGGI	Global Green Growth Institute
GHG	Greenhouse gas
GoN	Government of Nepal
GRI	Global Resources Institute
GWO	Grey wolf optimiser (in the context of metaheuristics)
IBRD	International Bank for Reconstruction and Development
ICEV	Internal combustion engine vehicle
IMF	International Monetary Fund
IRR	Internal rate of return
ITS	Information Technology Services
JICA	Japan International Cooperation Agency
KPI	Key performance indicator
LFP	Lithium-iron-phosphate (in the context of batteries)
MaaS	Mobility-as-a-Service
MoFE	Ministry of Forest and Environment
MoPIT	Ministry of Physical Infrastructure and Transport
NGO	Non-governmental organisation
NOx	Nitrogen oxides
NPV	Net present value
OECD	Organisation for Economic Cooperation and Development
PM	Particulate matter
PT	Public transport
SA	Simulated annealing (in the context of metaheuristics)
SDG	Sustainable development goal (in the context of the UN)
TCO	Total cost of ownership
TtW	Tank-to-wheel (in relation to emissions)
UNA	User needs assessment
UNEP	United Nations Environment Programme
USAID	United States Agency of International Development
VKM	Vehicle kilometre
VRU	Vulnerable road user
WHO	World Health Organisation
WtT	Well-to-tank (in relation to emissions)
WtW	Well-to-wheel (in relation to emissions)

1 BACKGROUND AND CONTEXT

The Kathmandu valley consists of 18 municipalities, including the capital city of Kathmandu. It is the biggest urban centre in Nepal with a combined population of more than 2.5 million. Nepal's GDP per capita was US$1,336.5 in 2022 (IBRD, 2024) and the country's CO2 emissions accounted for 0.06% of global emissions in 2010/11 (MoFE, 2021). Nepal does not have fossil fuel reserves and relies on imports, at an average annual growth rate of more than 8% since 1991 (GGGI, 2018a). In addition, fuel prices are volatile putting pressure on national budgets (CEN, 2020). Most of Nepal's electricity comes from hydropower generated within the country. Nepal's total installed generation capacity is 1,182 MW against a peak electricity demand of 1,320 MW in fiscal year 2018-2019. The remaining requirements were fulfilled by importing electricity from India, mainly to balance the shortage of power in winter (dry season). In the coming years, Nepal will have surplus electricity (mainly in the wet season and during off-peak hours) through hydropower projects, which are in different stages of development and construction. This will support the deployment of electric vehicles in Nepal. The second Nationally Determined Contribution of Nepal (GoN, 2020) stipulates that 15% of the total energy demand will be supplied from renewable energy sources (mini and micro-hydro power, solar, wind and bioenergy) by 2030. Likewise, it refers to an increased electric vehicle sales target of 25% for all private passenger vehicles and 20% for all 4-wheeler public passenger vehicles (excluding electric rickshaws and electric tempos) until 2025, resulting in reduced fossil fuel energy demand.

1.1 GEOGRAPHY, SOCIO-ECONOMIC, AND ADMINISTRATIVE CONTEXT

Location and topography

The Kathmandu valley is bowl-shaped, surrounded by mountain ranges. It stands at an elevation of approximately 1,425 metres above sea level. According to Nepal Road Standard (2013),[1] Nepal's vehicle maximum gradient is 12% for a design speed of 20km/h, and 10% and 9% for design speeds of 30 and 40 km/h respectively.

Climate

Nepal's climate is influenced by the Himalayan mountain range and the South Asian monsoon. Kathmandu has four seasons (summer, autumn, winter, and spring). The average temperature goes from minimum 2˚ to maximum 30˚, with 110 rainfall days (1,450mm).

Population/urbanisation

Out of the 2.5 million residing in Kathmandu valley, around 1 million is the population of Kathmandu city alone. It is one of the fastest-growing metropolitan areas in South Asia, growing at 6.5% per year (Timsina et al., 2020). In 2020, Kathmandu experienced a population growth rate of 3.45%. Kathmandu accounts for 1/12 of Nepal's total population, with a population density of 20,288 people per square kilometre. The city is ethnically and culturally diverse and has a history of more than 2,000 years.[2]

1 http://kec.edu.np/wp-content/uploads/2017/06/Nepal-Road-Standard-2070-1.pdf
2 https://worldpopulationreview.com/world-cities/kathmandu-population

1.2 URBAN TRANSPORT

Modal shares

Road transport dominates transportation in Nepal, accounting for over 90% of the movement of passengers and goods (ADB, 2013). Buses (including minibuses) are one of the main modes of public transportation in the valley, followed by microbuses, vans and 3-wheelers (tempos). According to JICA/Department of Roads, about 27% of trips in Kathmandu are made on public transport – out of which bus accounts for 16.6%, minibus for 8%, tempos for 2.3%. In comparison, the percentage of trips by motorbikes was 25.8% in 2011 (JICA, 2012). The modal share of motorbikes increased almost threefold in two decades between 1991 and 2011 and it has probably increased further since 2011 as the number of motorcycles has continued to grow fast.

Vehicle fleet

The increase in vehicle registrations in Nepal is impressive, causing air pollution and health problems. According to the Department of Transport Management (DoTM, 2019), during 1990-2018 the total number of vehicle registration grew by 16% per year (refer to Figure 1). By March 2019, there were a total of more than 3.5 million vehicles registered in Nepal, a major share of which was concentrated in the Kathmandu valley. It is worth noting that although private vehicles (i.e., cars and 2-wheelers) make up 78% of the vehicle fleet, they carry only up to 10 % of the daily trips (CSE, 2012).

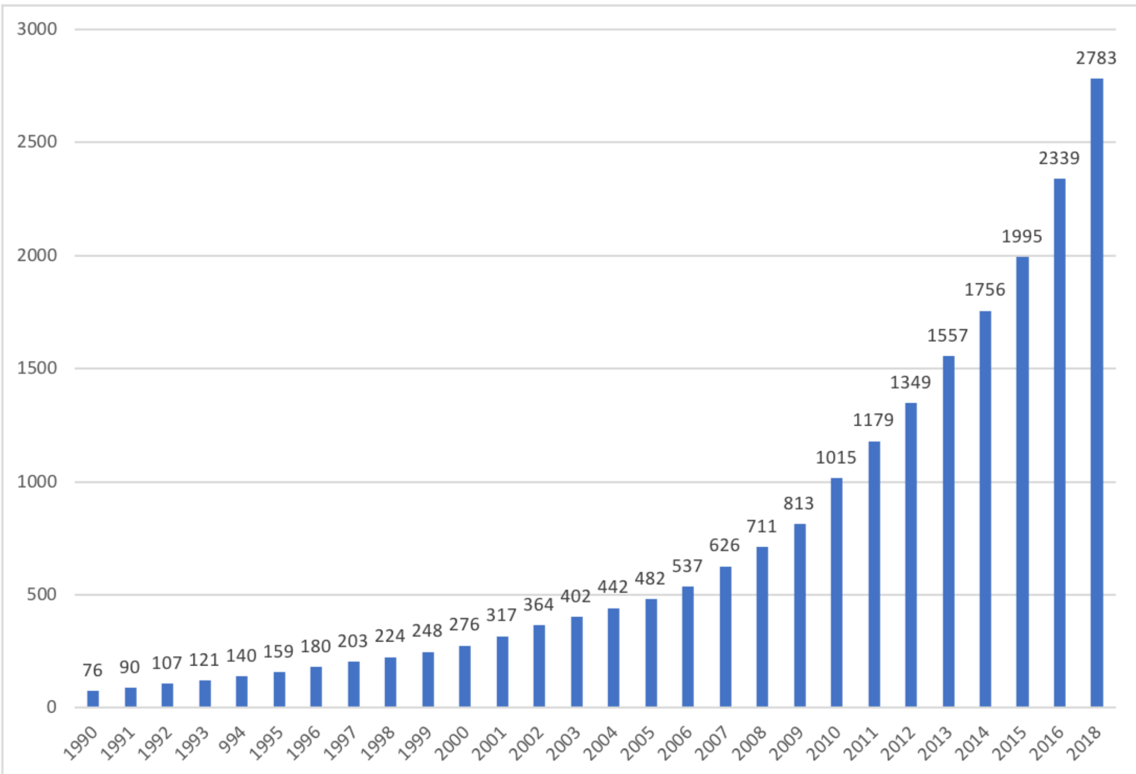


Figure 1. Total vehicle registration (in thousand) in Nepal
(Source: DoTM, 2019)

The highest growth is exhibited by motorcycles, which in the 1990-2018 period grew at an annual rate of 17% (Figure 2). As of March 2019, the number of motorcycles were 78.6% of the total number of vehicles registered.

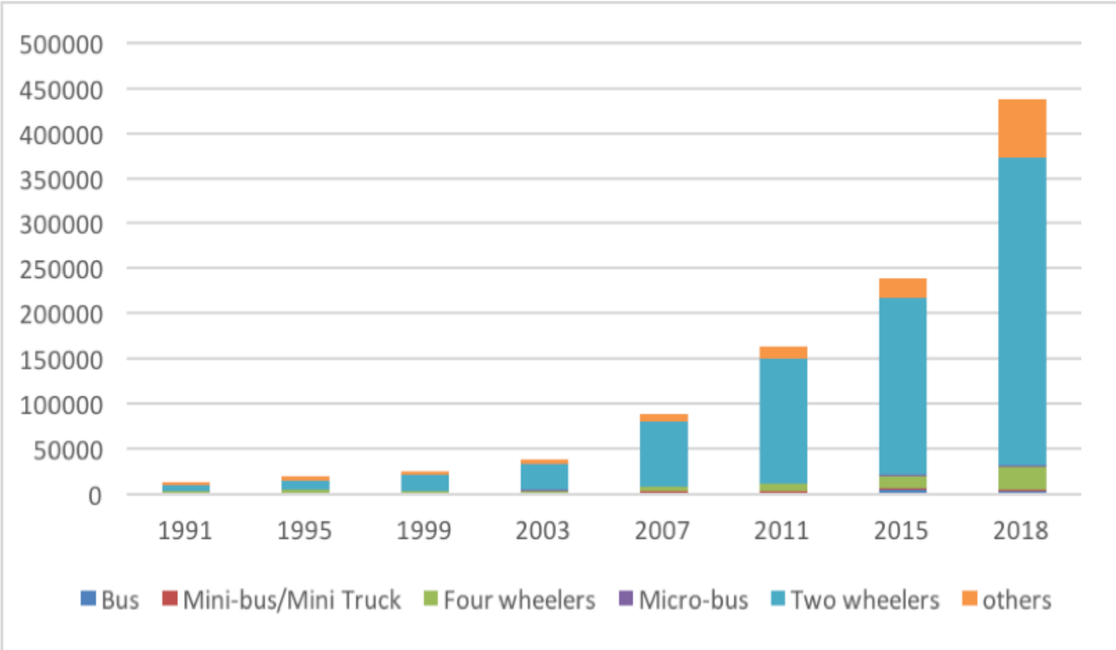


Figure 2. Composition of registrations by vehicle type
(Source: DoTM, 2019)

Public transport

In Kathmandu, the number of buses rose from 4,000 units in 1990, to more than 35,000 units in 2015. This category includes full size buses, minibuses, microbuses, and 3-wheelers (tempos). However, as a share of the total vehicle fleet, buses have declined from 11% of the total in 1990, to only 3% in 2015 due the rise of private vehicles (GGGI, 2018a). In the Kathmandu valley, public transport provision starts around 4:30am and stops after 9pm (night buses were introduced in 2012 but suspended soon after) with less than 25% plying after 8pm. After this hour, people without their own means of transport either use taxis or are transported by work-arranged means. The peak hours (8.30-11am and 5-7pm) are heavily dominated by people travelling for work or education. [3]

1.3. IDENTIFICATION OF MAIN PROBLEMS

With growing urbanisation and income, the demand for private vehicles increases fast also straining the available public transport services in the city. Adverse effects are observed in several directions.

3 https://openknowledge.worldbank.org/bitstream/handle/10986/17872/860850WP0Final0Box382164B000PUB-LIC0.pdf?sequence=1&isAllowed=y

Emissions and air pollution

According to recent data, the national public and private vehicle fleet, excluding commercial vehicles (such as trucks, minitrucks, and construction vehicles), generates about 4.5 million tonnes CO2 emissions per year, and 1.9 million tonnes in the Kathmandu valley (among others, Sadavarte et al., 2019). Vehicular emissions constitute around 38% of total emissions in Kathmandu alone (CEN, 2020). Enforcement problems of emission control have worsened the situation. Kathmandu is ranked as one of the most polluted cities in Asia. Vehicular emissions and more specifically traffic related particulate matter have serious health repercussions such as increased respiratory disease, mainly due to the old and inefficient diesel-powered vehicles. As shown in Figure 3, air pollution varies with seasons, getting its higher values during

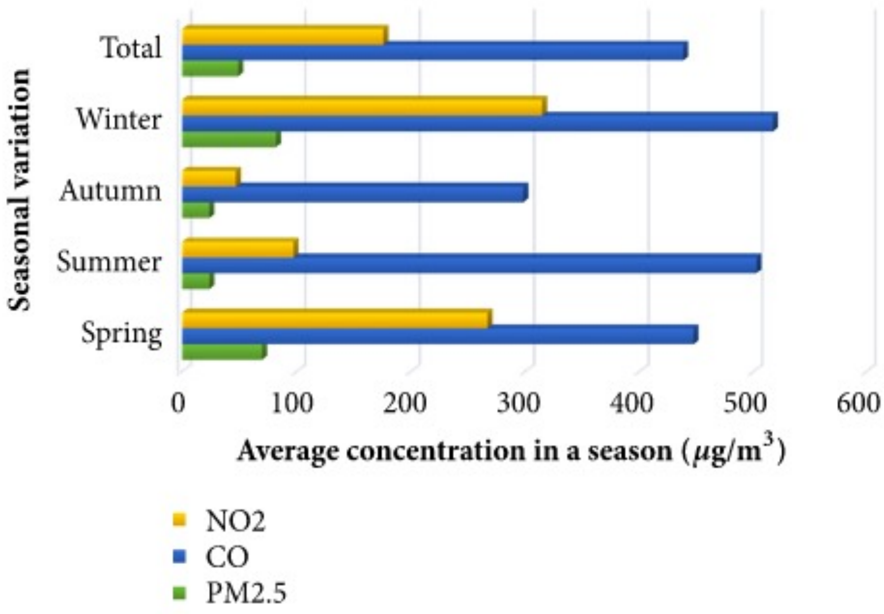


Figure 3. Outdoor air pollution in Kathmandu Valley in 2015
(Source: Saud & Paudel, 2018)

winter and spring (Saud & Paudel, 2018).

To alleviate air pollution in the Kathmandu valley, the Government of Nepal banned the operation of highly polluting 3-wheeler diesel vehicles, as well as the imports of new 2-stroke and second-hand vehicles from 1999 onwards. Since 2017, the Government of Nepal has also banned in the Kathmandu valley the operation of public vehicles more than 20 years in age. The introduction of Safa Tempos (e-3-wheelers) in late 1990s and the more recent imports of private e-cars, e-scooters, and e-buses are mainly the result of these developments (CEN, 2020).

Public transport regulation and monitoring

Public transport in the Kathmandu valley is exclusively managed and operated by private companies or individuals and co-operatives (such as Sajha Yatayat). The government support for public transport is non-existent, apart from lower import taxes for this class of vehicles. Public transport vehicles are typically old and not well maintained. Until 2018, operation was governed by the syndicate system, which fixed routes, allowed higher fares, and impeded competition. Considered as a significant barrier for prospective transport entrepreneurs and leading to deteriorated quality of customer services, the system was abolished in 2018 (IBRD, 2019). However, in practice there are still challenges for small scale investors willing to invest in public transport, affecting the introduction of e-mobility.

Comfort, safety, and frequency

Public transport services in Kathmandu have not yet integrated real time information on arrivals and departures, with the noticeable exception of the Mero Sajha app covering just Sajha Yatayat. People just wait at the stops and embark as the vehicles arrive – resulting in cramped conditions and overcrowding particularly during peak hours and mainly in smaller vehicles such as vans. Disabled people, people travelling with young children and luggage find public transport use difficult. However, smaller public transports are still being preferred due to their ability to access narrow streets (e.g. secondary and tertiary routes) and bring passengers closer to their destinations. In contrast, buses usually run along the primary routes. Tempos (electric and gas 3-wheelers), run mostly by women drivers, are preferred by many travellers for safety reasons. They have a limited top speed (around 30 mph) and drivers do not permit overloading that can create stability problems (IBRD, 2019).

1..4. DESCRIPTION OF THE DEMONSTRATION PROJECT

The Kathmandu demonstration action aims to assist creating an ecosystem of electric mobility in the valley to enhance public transport. It includes the conversion of a diesel bus into an e-bus, the remodelling of Safa Tempos (e-3 wheelers) for passenger and cargo services, the conversion of a petrol run minitruck to electric, the new design of e-3 wheelers with a multi-use concept (passenger, cargo, and waste), the design of an e-shuttle van, and the potential improvement of vehicle integration services with the introduction of a cashless payment system. All project activities are designed to be carried out by local manufacturers with imported equipment and technical support from the consortium.

Conversion of diesel bus to e-bus

The conversion of an old diesel bus to an e-bus involved primarily replacing drive system components such as the motor, transmission, and rear axle. The necessary components for this conversion were imported and assembled locally. To aid the demo project, suitable simulation was employed to facilitate the design, optimisation, and development of a model. Furthermore, data loggers were used to measure and establish local drive cycles for calculating the required battery capacity.

Prototypes of e-3 wheelers

The conversion of an old diesel bus to an e-bus involves primarily replacing drive system components such as the motor, transmission, and rear axle. The necessary components for this conversion are being imported and assembled locally. To aid the ongoing demo project, suitable simulation is being employed to facilitate the design, optimisation, and development of a model. Furthermore, data loggers are being used to measure and establish local drive cycles for calculating the required battery capacity.

Through a multi-purpose concept, local manufacturers selected under a SOLUTIONSplus local innovators call redesigned currently running e-3 wheelers (Safa Tempos) into: (i) modular e-3 wheelers (new design), and (ii) a remodelled Safa Tempo suitable for passenger and cargo applications:

- Modular e-3 wheelers: A local manufacturer developed prototypes for a modular e-3 wheeler, providing deployment flexibility. With the same or minimal change in the technical specifications and main body, vehicle use can vary according to need. The required components for the prototypes were either imported or locally manufactured. The prototypes (in total four units) include passenger EV-mini Safa Tempo (6-seater), and cargo e-trike. The initial financial assessment of the originally planned municipal waste e-trike, however, found this vehicle less cost effective than the prior petrol-run solution. As such, this component was replaced by the conversion of a minitruck into an e-4 wheeler municipal waste collector (refer to Section 3.9 below).
- Remodelled Safa Tempo: It included design, development, and deployment of improved Safa Tempo (two units) that are suitable for passenger and cargo services and will support entrepreneurs (both owners and investors) in modifying their existing vehicles improving their performance and sustainability.

Prototype of e-shuttle van

One prototype of e-shuttle van (4-wheeler, 6-seater) was developed to replace conventional cars and vans used for tourist pick-up/drop-off and sightseeing in the inner city. Lalitpur Metropolitan City is planning to offer more such vehicles in Kathmandu mostly for heritage sightseeing.

Remodelled minitruck

A pick-up truck (namely petrol-powered Tata Ace), widely used for urban delivery, was remodelled into electric. Online delivery services currently exhibit a strong demand for such vehicles and the electrified ones through remodelling would additionally lower the carbon emissions.

Prefeasibility of a MaaS application including an integrated electronic payment system

The project also assessed the possibility of introducing a Mobility-as-a-Service (MaaS) application in Kathmandu offering smart services for fleet management including an integrated electronic payment system. Following preliminary results, the implementation of MaaS application has been subsequently excluded from the scope of SOLUTIONSplus.

1.5. STAKEHOLDERS AND USER NEEDS

The SOLUTIONSplus Kathmandu team has identified 20 experts under eight main stakeholder groups for the initial user needs assessment (UNA). Interviews were arranged with 15 of these experts. An online survey was further circulated among additional stakeholders from groups that had already provided sufficient feedback. Table 1 presents the contacted organisations by group and UNA activity. This section summarises the key findings of the user needs assessment. For a comprehensive discussion refer to D 1.3 (User needs assessments) and the Kathmandu User Needs Assessment – City Report (here).

Stakeholder Group	Organisation	UNA activities	
		Online survey	Interview and KPI weights
Public Transport Operators	Sajha Yatayat	√	√
	Private operators and Nepal Transport Entrepreneurs Association	√	√
National Authorities	Ministry of Physical Infrastructure and Transport, Department of Transport Management	√	√
Local Authorities	Lalitpur Metropolitan City and Kathmandu Metropolitan City	√	√
Local manufacturing companies	Shree Eco-Visionary and Abhiyantri Karmashala	√	√
	Nepal Electric Vehicle Pvt Ltd and AGNI ENERGY PVT.LTD.	√	
Service Providers	Wind Power Nepal Private Limited	√	√
Donors	Global Green Growth Institute and Asian Development Bank	√	√
Academia	Kathmandu University and Tribhuvan University	√	√
Environmentalists/ NGOs	Clean Energy Nepal	√	√
	Weekly Nepal/Renewable Energy Confederation of Nepal	√	√
	Aeloi Technologies	√	

Table 1. Relevant stakeholders and UNA engagement

Aims of the city in relation to urban mobility

Air pollution is the main environmental challenge in Kathmandu (which is well beyond the threshold of WHO). The increasing number of fossil-fuelled private vehicles and the resulting vehicle emissions have seriously affected public health in the city. The situation is aggravated by the vehicle condition (old and not maintained), which is not controlled sufficiently. Furthermore, the share of public transport is low in the city (27% of the total trips). The city needs higher public transport ridership (an increase by at least 50%) to reduce vehicle emissions and improve air quality. EVs for public transport are, thus, seen as a solution to this challenge. It follows that public transport needs to become more effective, efficient, and attractive to riders. This will also enhance the economic growth of the transport service sector.

On a positive note, almost all electricity generated in Nepal comes from the hydropower plants of the country. In the coming years, Nepal will have surplus electricity through new hydropower projects, which are in different stages of development and construction. Nepal needs to tap this electricity generation plan and go into the direction of an environmentally friendly transport system, which will also support reducing the external trade deficit (mainly fossil fuel import).

Due to the higher upfront cost, the public transport operators are reluctant to invest in e-buses. Moreover, they have not yet been convinced that e-buses have lower operating costs and increase the comfort level of the passengers. The improved comfort level could induce additional demand leading to higher revenues and/or lower total costs.

Regulations

The government plans to promote EVs in Nepal and is in the process of drafting the supporting policies. However, there is the need for intensifying the required effort in this direction. Existing regulations in need of re-visiting include:

- Provision of financial incentives that can be critical in view of the high capital requirements of EVs (e.g. green climate funds, subsidies and favourable tax treatment until the e-mobility technology matures and market penetration improves, reduced tax on EV components for local manufacturers);
- Utilisation of the accumulated pollution taxes on fossil-fuelled vehicles for the promotion of EVs; and
- Reform EV tax (consider measures such as annual and/or income tax breaks for electric public transport besides 1% import duty).

SOLUTIONSplus project and demo prototypes

On the targeted uses of e-vehicles, stakeholders expressed the view that passenger transport is of higher priority than transport of goods, also indicating the city centre and suburbs as the targeted areas for EV use.

All the stakeholder groups acknowledged that the SOLUTIONSplus project with its numerous international partners and its variety of city networks provides a massive platform for knowledge exchange and diffusion. This is even more important when it comes to a new technology such as EVs. So, knowledge, networking and the demo project are all important for Kathmandu.

The following stakeholder comments provide interesting insights in relation to SOLUTIONSplus demo prototypes:

- Routing: In line with findings of recent projects on urban transport in the Kathmandu valley and aiming at reduced congestion and emissions, some stakeholders suggested the gradual discouragement of smaller vehicles such as e-3 wheelers and microbuses from using the city's main routes, and their restriction to secondary and tertiary routes.
- Vehicle integration: A mobile application for vehicle integration that provides information on trip plans and real time vehicle arrivals and departures would be useful and urgently needed.
- Bus conversion: The cost of the converted bus is expected to be much lower than that of a new bus and the relevant SOLUTIONSplus prototype can be a good example for raising awareness on the concept among private operators.
- Technical standards: There is an urgent need for technical standards and operational guidelines both for e-buses (and EVs in general) and charging stations. SOLUTIONSplus could support the request for such technical standards.
- Prototypes: Two stakeholders expressed concerns over the rationale of remodelling e-3 wheelers if the new law is going to prohibit their use along the city's primary routes. Alternatively, if these prototypes are converted into e-4 wheelers, Safa Tempos could be rescued, as licensing will become easier. In general, the conversion of smaller vehicles can be very useful in Kathmandu and the SOLUTIONSplus demo prototypes exhibit significant potential for transforming mobility in Nepal through proper scaling-up.

Obstacles, limitations, and barriers for EVs

Stakeholders highlighted several factors that can challenge the successful implementation of e-mobility in Kathmandu. The reliability of electricity supply (transmission lines, distribution network and voltage fluctuations) needs to be improved to support the EV market uptake. EVs are a new transport system in Nepal and the lack of charging infrastructure is another serious issue. In view of lower public demand for electricity overnight, several stakeholders pointed to the overnight charging as the optimal option for Kathmandu; and given a normal travel range of 120-130 kms per day for public transport in the city, charging once a day would be sufficient.

The vehicle conversion was still not legally accepted when the project was initiated. An amendment was later adopted allowing conversion for a limited time (3 years – starting from March 2022[4]). SOLUTIONSplus demos can showcase the technical and financial viability of conversions.

The lack of local capacity to operate and maintain EVs is a major concern for all stakeholders. There is a need for training curricula for workshop mechanics, as well as 'Train the Trainers programme' that delivers knowledge in a simple and practical manner. Moreover, the decision makers/policy makers/bureaucrats need to become aware of the EV benefits.

Obstacles, limitations, and barriers for EVs

Stakeholders highlighted several factors that can challenge the successful implementation of e-mobility in Kathmandu. The reliability of electricity supply (transmission lines, distribution network and voltage fluctuations) needs to be improved to support the EV market uptake. EVs are a new transport system in Nepal and the lack of charging infrastructure is another serious issue. In view of lower public demand for electricity overnight, several stakeholders pointed to the overnight charging as the optimal option for Kathmandu; and given a normal travel range of 120-130 kms per day for public transport in the city, charging once a day would be sufficient.

The vehicle conversion was still not legally accepted when the project was initiated. An amendment was later adopted allowing conversion for a limited time (3 years – starting from March 2022). SOLUTIONSplus demos can showcase the technical and financial viability of conversions.

The lack of local capacity to operate and maintain EVs is a major concern for all stakeholders. There is a need for training curricula for workshop mechanics, as well as 'Train the Trainers programme' that delivers knowledge in a simple and practical manner. Moreover, the decision makers/policy makers/bureaucrats need to become aware of the EV benefits.

Business model

Given the common practice of private sector's involvement in the provision of public transport services in the city, several stakeholders see the scheme of public-private

4 https://nepaldrives.com/government-to-allow-conversion-of-ice-vehicles-into-electric-or-other-alternative-fuel-vehicles/

partnerships as a promising business model, basically due to its advantages in relation to the necessary investments. In any case, the current revenue stream determined by the government may not be able to support the necessary transition to e-mobility, signifying the need for external funds.

Implications for planning and urban development

The full transition to e-mobility in the long-term generates the need for seriously enhanced planning in the public transport domain. Currently, various institutions are involved in planning and development of transport and road management in Kathmandu, but not in a cohesive manner. This situation hinders smooth planning and infrastructure development, despite the willingness of local authorities to support sustainable transport. Acknowledging this weakness, the government has constituted through a special legal act the 'Kathmandu Valley Public Transport Infrastructure Authority,' which aims to establish an entity responsible for planning, managing, and operating the public transportation system in the Kathmandu Valley. The authority is responsible for making the public transportation in the valley accessible, easy, reliable, and safe. According to the bill, the authority will fix the routes for public transportation and set standards for vehicles.

Additionally, the requirements imposed by e-mobility need to be integrated in urban planning and infrastructure development. On the electricity supply system, there is the need for a massive upgrading of the network to bear the additional load on the grid associated with EVs.

2 KEY PERFORMANCE INDICATORS (KPIS)

2.1 PRIORITIZATION OF KPIS ADDRESSING THE SPECIFIC CITY NEEDS

As explained in the methodology section of D1.6 – Vol.1 (Section 2.1.4), the priorities of the stakeholders are formally determined through the weights assigned to the selected attributes (KPIs). The attribute weighting activity in Kathmandu took place in conjunction with the stakeholder interviews organised in relation to the user needs analysis of Section 1.5. The procedure described in Section 2.1.4 (Vol.1) was followed for all 15 interviewed stakeholders, representing eight stakeholder groups (refer to Section 1.5).

Figure 4 exhibits the mean values of the weights received from the 15 stakeholders for all L1, L2 and 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.

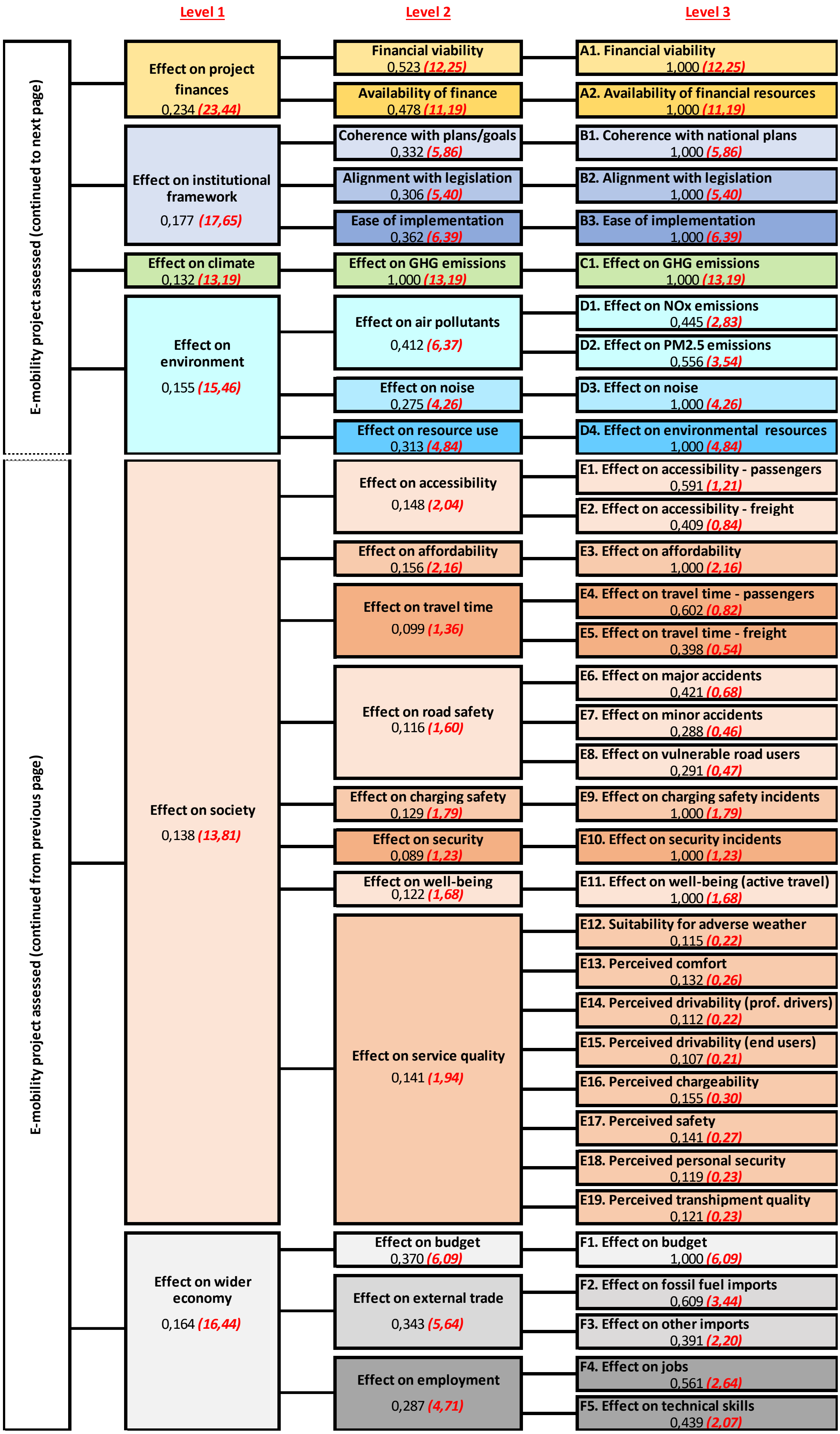


Figure 4. Attribute weights indicated by the Kathmandu stakeholders

With a cumulative weight of 23.44, project finances appear as the main priority of the stakeholders apparently reflecting the necessity to invest in e-mobility even in the case the proposed project is not self-sustainable. In line with the findings of the user needs analysis (refer to Section 1.5), the institutional framework constitutes the second highest priority with a weight of 17.65, probably signifying the entrance barriers of nascent technologies on top of the institutional/political realities of the country. Interestingly, the effects on the wider economy (16.44) attract significant attention, about 1 percentage point above environmental concerns (15.46), which, in view of the pollution problems in the Kathmandu valley and the well-known effect of e-mobility in this regard, rank lower than expected in the stakeholder priorities. With a weight of 13.19, the less visible effects on climate change exhibit the lowest priority.

Some interesting observations can be made among the L2 attributes:

- The ‘availability of finance’ indicator gets a weight comparable to that of ‘financial viability’ (11.19 vs. 12.25). This can be explained either by the expectation that an e-mobility project may not be sustainable financially despite generating social benefits that exceed costs (in which case external funding would be necessary) or by the need to provide low-interest loans to support the relatively high initial investments required.
- In relation to the institutional framework, the ‘ease of implementation’ gets a higher weight than ‘alignment with legislation,’ indicating: (i) the existence of administrative barriers also confirmed by the user needs analysis, and (ii) the importance of project ownership by the national and local authorities.
- The ‘effect on affordability’ is the highest priority of the stakeholders among the eight societal L2 indicators, signifying the role of pricing in the promotion of public transport in the city.

In relation to the L3 attributes, it is worth noting the preference of the effect on fossil fuel imports (3.44) over other imports (2.20), as well as the preference of additional jobs (2.64) over increased technical skills (2.07), which is used as a proxy for wages.

Although the stratification of the attribute weights by stakeholder groups needs to be handled with caution due to the small samples involved, some indicative findings result from such comparisons. From Figure 5, one can infer that:

- The stakeholders who assign above average weights (20.22) to ‘project finances,’ in addition to academia (22.63), are the city (28.18) and national (22.73) authorities, who probably have to cover any financial deficits.
- The institutional issues have overwhelmingly higher importance to city authorities than any other group, apparently due to the ongoing discussion on jurisdiction over public transport design and operation in the Kathmandu metropolitan area, as well as the debated operation of the foreseen 300 new e-buses by the municipalities.
- A rather surprising observation concerns the highest importance assigned by the public transport operator to the environment (among all KPI groups), which is usually not the case. A possible explanation relates to the fact that the interviewed representative of Sajha Yatayat happens to be the chairman of Clean Energy Nepal (CEN), an NGO focusing on research-based education and advocacy campaigns on issues related to sustainable energy use and environmental conservation.
- On the contrary, the emphasis placed by environmentalists/NGOs on the climate- and environment-related attributes is of no surprise at all.

- The preference of donors on the GHG emission reduction is also worth noting, maybe due to the macro-regional role of these stakeholders.

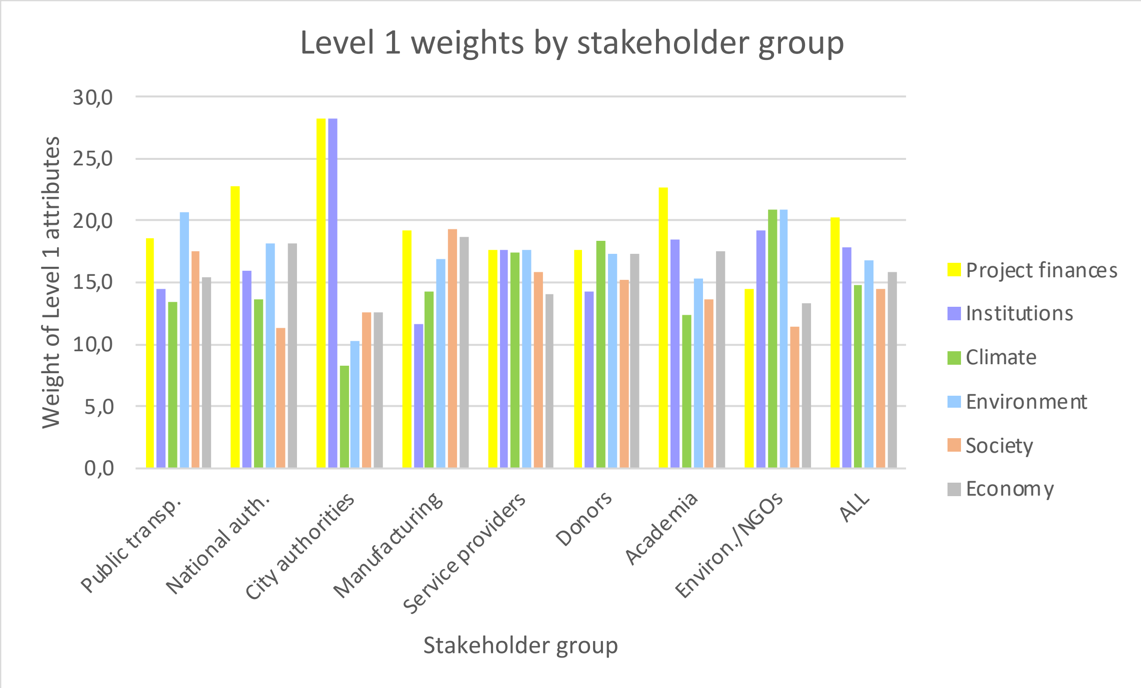


Figure 5. Level 1 weights by stakeholder group

The main finding of Figure 6 relates to the selection by four out of the eight stakeholder groups of implementation issues as the most important institutional aspect, indicating the existence of administrative barriers and the lack of policy ownership by the relevant actors. Note that the groups sharing this view include all market players (manufacturing sector, service providers, and public transport operators) plus the national authority represented in the sample.

The weights assigned by the stakeholder groups on societal attributes are depicted in Figure 7. It is interesting to note that:

- Affordability and accessibility are the highest priorities for most of the stakeholder groups.
- Road safety is the dominant concern of the public transport operator.
- City authorities, service providers and environmentalists/NGOs exhibit a high interest for service quality.
- Charging safety comprises a notable concern of academia, service providers, manufacturers, and the national authorities.

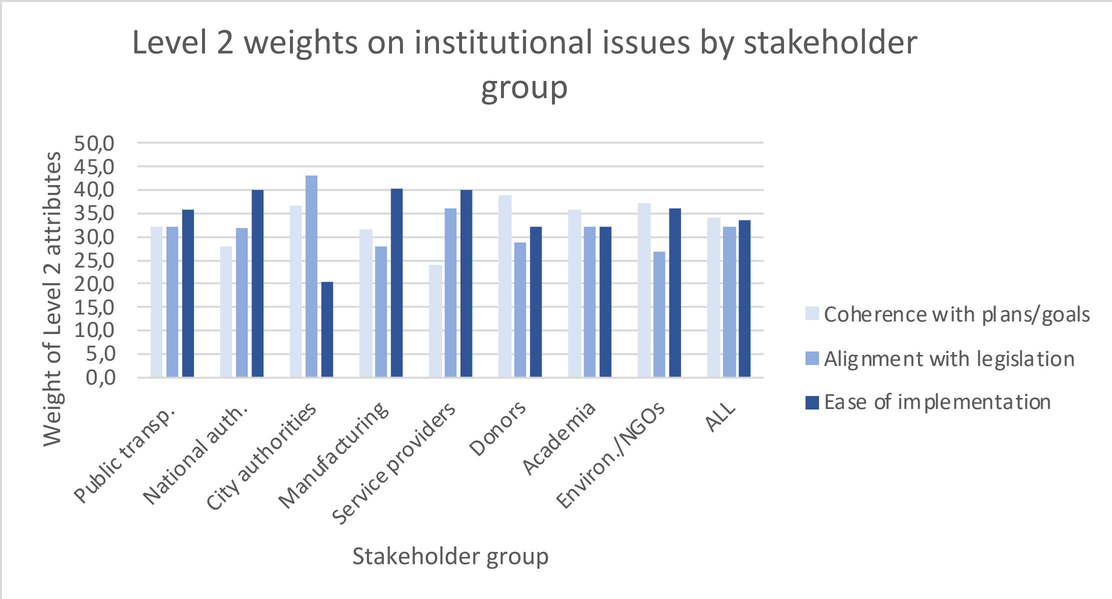


Figure 6. Level 2 weights on institutional issues by stakeholder group

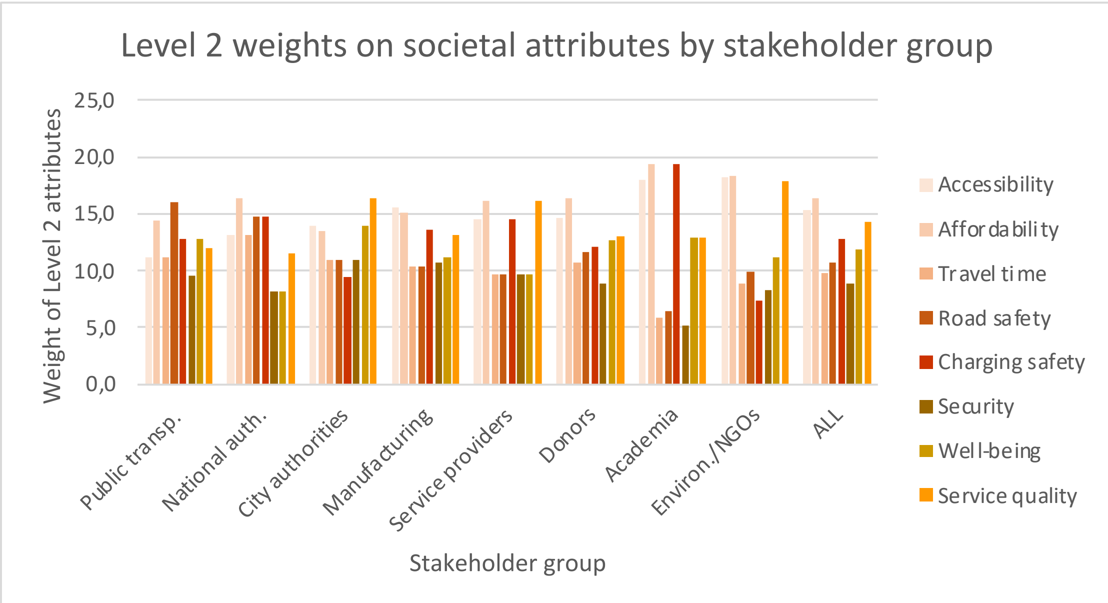


Figure 7. Level 2 weights on societal attributes by stakeholder group

2.2 KPI ESTIMATION METHODS AND DATA NEEDS

Data requirements are determined by the KPIs selected for the impact assessment in conjunction with the methods to be deployed in their estimation. Table 2 briefly presents the Level 2 KPIs and the corresponding estimation methods and data needs. Note that a distinction is provided for the estimation method, depending on whether the assessment concerns the demonstration project/component or the corresponding scaled-up project. The absence of a demo entry in the estimation column signifies no expected effect at demonstration level. Some indicative data sources are provided in Table 3, while Table 4 lists the stakeholders and other institutions that are expected to be involved in data provision and collection.

Key Performance Indicators		Estimation method	Data needs
Level 1	**Level 2**		
Effect on project finances	**Financial viability**	**Scaled-up:** The NPV, IRR, CER and payback indices will be calculated via specialised financial assessment tools calibrated for the specific applications. The total cost of ownership (TCO) calculations of the UNEP eMob model can also be used. **Demo:** No need to go beyond TCO estimates, as the purpose is to collect the data required for assessing the financial viability of the scaled-up project. Possible economies and diseconomies of scale effects need to be considered in applying demo figures on the scaled-up project.	• Detailed capital, operating and maintenance costs on an annual basis for all project vehicles and for the duration of their expected lifespan • One-time project preparation (if applicable) and residual values • Cost structure of the corresponding baseline solutions (to be replaced by the proposed ones) • Expected revenues of the executing agency • Both costs and revenues are estimated based on the corresponding volume figures and unit prices
	Availability of finance	**Scaled-up:** Direct rating (Likert scale)	• Available private, government and donor funds, credit lines, etc. to be used for the scaled-up project in case external funding is required
Effect on institu-tional frame-work	**Coherence with national plans/goals**	**Scaled-up:** Direct rating (Likert scale)	• National plans and development goals in relation to SDGs, climate change, energy policies, transport policies, environmental protection policies, etc. • Similar plans and goals at regional/city level
	Alignment with legislation	**Scaled-up:** Direct rating (Likert scale)	• National legislation concerning manufacturing, conversion, licensing, operation and decommissioning of urban transport vehicles with emphasis on EVs • Similar regulations at regional/city level • Technical standards for EV manufacturing and charging infrastructure
	Ease of implementation	**Scaled-up:** Direct rating (Likert scale)	• Implementation of existing legislation • Enforcement mechanisms • Administrative barriers

Table 2. KPI estimation method and data needs

Key Performance Indicators		Estimation method	Data needs
Level 1	**Level 2**		
Effect on climate	**Effect on GHG emissions**	**Scaled-up:** Application of the UNEP eMob model or ad hoc calculations based on the demo results **Demo:** Calculation of the GHG emissions abated by comparing the EV carbon emissions (if any) to those of the do-nothing practice	• Socio-economic data (population, regional GDP, expected GDP growth rate until target year) • Fleet composition (existing vehicle stock, projected sales until target year, sales composition by technology) • Emission standards by year of introduction • Fuel quality standards by year of introduction • Existing and projected charging infrastructure • Fuel economy of vehicles involved • Operational characteristics (annual mileage, load factor, expected lifespan) • The default emission figures provided by the UNEP eMob model for the vehicles involved might be sufficient for the demo components
Effect on environ-men	**Effect on air pollutants**	**Scaled-up:** Application of the UNEP eMob model or ad hoc calculations based on the demo results **Demo:** Calculation of the NOx and PM2.5 emissions abated by comparing the EV corresponding emissions (if any) to those of the do-nothing practice	Ibid.
	Effect on noise	**Scaled-up:** Expected reduction in noise due to the electric drive as reported in literature. **Demo:** On-site measurements & interviews	• Speed-noise diagram for diesel vehicles • Speed-noise diagram for EVs
	Effect on resource use	**Scaled up:** Quantification of mechanical parts and batteries recycled **Demo:** Ibid.	• Weight of recycled parts (due to conversion) as a percentage of total weight • Battery recycling infrastructure • Volume of recycled batteries generated by project activities

Table 2. KPI estimation method and data needs (continued)

Key Performance Indicators		Estimation method	Data needs
Level 1	Level 2		
Effect on society	**Effect on accessibility**	**Scaled-up:** No effect on accessibility is expected by the planned SOLUTIONSplus initiatives	N/A
	Effect on affordability	**Scaled-up:** Effect is possible only in case of substantial cost savings due to the conversion of old diesel buses to e-buses	• Pricing policy of Sajha Yatayat
	Effect on travel time	**Scaled-up:** Possible effect due to improved reliability of e-buses in comparison to diesel ones	• Delays due to malfunctions of diesel buses • Technical reliability of e-buses vs. diesel buses
	Effect on road safety	**Scaled-up:** Comparison of EVs with traditional vehicles with respect to road accidents per vkm **Demo:** Monitoring and reporting of safety incidents during demo period & interviews	• Official annual national/regional/city statistics on road accidents by type (fatalities/major injuries, minor injuries/material damages, near misses) • Official annual statistics of road accidents by gender • Official annual statistics of road accidents involving VRUs • Official statistics of accidents involving EVs (Nepal or abroad)
	Effect on charging safety	**Scaled-up:** Comparison of EVs with traditional vehicles with respect to charging safety incidents per thousand recharging/refuelling operations **Demo:** Monitoring of charging safety incidents during demo period & interviews	• Official national/regional/city statistics on safety incidents during refuelling operations • Official statistics on safety incidents during recharging operations of EVs (in Nepal or abroad)
	Effect on security	**Scaled-up:** Comparison of EVs with traditional vehicles concerning security incidents per vkm **Demo:** Monitoring of security incidents during demo period & interviews	• Official national/regional/city statistics on security incidents of traditional vehicles • Official statistics on security incidents involving EVs (in Nepal or abroad)
	Effect on well-being	**Scaled-up:** No effect on accessibility is expected by the planned SOLUTIONSplus initiatives	N/A
	Effect on service quality	**Scaled-up:** Direct rating (Likert scale)	• User perceptions on suitability for climate changes, comfort, drivability (by professional drivers), chargeability, safety, personal security, and transhipment quality

Table 2. KPI estimation method and data needs (continued)

Key Performance Indicators		Estimation method	Data needs
Level 1	**Level 2**		
Effect on wider economy	**Effect on budget**	**Scaled-up**: Comparison of required investment to the annual budget of the executing agency	• Annual budget of the executing agency
	Effect on external trade	**Scaled-up:** Expected reduction in imported values due to lower fossil fuel quantities and the conversion activities	• Reduction of fossil fuel consumption due to the introduction of EVs • Reduction of import value due to converting existing buses
	Effect on employment	**Scaled-up:** Expected effects on jobs and technical skills due to the introduced e-mobility activities based on published information & interviews	• Effects on employment due to the introduction of e-mobility reported in Nepal and abroad • Human resources required for the conversion activity • Availability of necessary skills

Table 2. KPI estimation method and data needs (continued)

Journal articles	Sadavarte, P., Rupakheti, M., Bhave, P. V., Shakya, K., & Lawrence, M. G. (8. March 2019). Nepal Emission Inventory (NEEMI): a high resolution technology-based bottom-up emissions inventory for Nepal 2001-2016. Atmospheric Chemistry and Physics Discussions.
	Nepal, A. (March 2020). Mitigation of GHG Emission by Replacing Diesel Buses with Electric Buses in Kathmandu Valley "A Case Study of Sajha Yatayat". Journal of Innovations in Engineering Education , 3 (1).
	Mool, E., Bhave, P. V., Khanal, N., Byanju, R. M., Adhikari, S., Das, B., et al. (March 2020). Traffic Condition and Emission Factor from Diesel Vehicles within the Kathmandu Valley. Aerosol and Air Quality Research , 20 (3), S. 395-409.
	Bhattarai, K., Yousef, M., Greife, A., & Lama, S. (2019). Decision-Aiding Transit-Tracker Methodology for Bus Scheduling Using Real Time Information to Ameliorate Traffic Congestion in the Kathmandu Valley of Nepal. Journal of Geographic Information System , 11, S. 239-291.
	Shrestha, H. R. (2018). Existing Condition of Urban Mobility in Kathmandu Valley. Invention Journal of Research Technology in Engineering & Management (IJRTEM) , 2 (6), S. 86-96.
	Das, B., Bhave, P. V., Puppala, S. P., & Byanju, R. M. (2018). A Global Perspective of Vehicular Emission Control Policy and Practices: An Interface with Kathmandu Valley Case, Nepal. Journal of Institute of Science and Technology. Tribhuvan University.
Donor reports	GGGI. (2018). Investment Projects for Electric Mobility:Accelerating Implementation of Nepal's Nationally Determined Contribution. Global Green Growth Institute. Kathmandu: Government of Nepal.
	GGGI. (2018a). National Action Plan for Electric Mobility: Accelerating Implementation of Nepal's Nationally Determined Contribution. Global Green Growth Institute. Kathmandu: Government of Nepal.
	GGGI. (2018b). A Pre-feasibility Study: Deploying Electric Buses in the Kathmandu Valley. Global Green Growth Institute. Kathmandu: Government of Nepal.
	The World Bank. (2019). Nepal Infrastructure Sector Assessment: Private Sector Solutions for Sustainable Infrastructure Development. Washington DC: International Bank for Reconstruction and Development/ The World Bank.
	The World Bank. (2020). Delivering Road Safety in Nepal: Leadership Priorities and Initiatives to 2030. International Bank for Reconstruction and Development/ The World Bank.
	ADB. (2020). Nepal: Kathmandu Sustainable Urban Transport Project. Asian Development Bank.
	The World Bank. (2013). Gender and Public Transport. The World Bank Group.
	JICA. (2017). The Project on Urban Transport improvement for Kathmandu Valley in Federal Democratic Republic of Nepal. Japan International Cooperation Agency. Federal Democratic Republic of Nepal,Department of Roads (DOR), Kathmandu Valley Development Authority (KVDA).
GoN reports	Government of Nepal. (2013). Nepal Road Standard 2070. Ministry of Physical Infrastructure & Transport, Department of Roads. Kathmandu: Government of Nepal.
	Giri, A. S. (2001). Emission Regulations and Environmental Policies in Nepal. Ministry of Industry, Commerce and Supplies.

NGO reports	CEN. (2020). Fuel Economy Labelling of LDVs in Nepal. Clean Energy Nepal.
Regula-tion	Government of Nepal. (1997). Motor Vehicles and Transport Management Rules, 2054 (1997). Nepal Law Commission. Government of Nepal. (2020). Second Nationally Determined Contribution (NDC). Kathmandu.
News Articles	Kumar, H. M. (21 January 2020). Nepal's transition to Euro VI fuels not likely to significantly impact air pollution levels. Retrieved on 10 January 2021 from The Kathmandu Post: https://bit.ly/2Lie6hQ THT. (02 March 2018). Imported vehicles to meet Euro IV norms. Retrieved on 16 December 2020 from The Himalayan Times: https://bit.ly/2MW1768 Investopaper. (17 June 2020). Government Announces New Electricity Tariff Rates in Nepal. Retrieved on 18 January 2021 from Investopaper: https://bit.ly/36GJ76C
Presen-ta-tion (NGO)	Neupane, P. (n.d.). Developing Clean and Efficient Vehicle and Fuel Policy for Nepal. Clean Energy Nepal.
Presen-ta-tion (GoN)	Shrestha, C. M. (n.d,). Air Quality and Cleaner Used Vehicles: Case of Nepal. From https://bit.ly/3cHHcCH

Table 3. Indicative data sources

Type of data	Institution (source)
Socio-economic data (GDP, population, external trade, employment)	IMF (Country data, Mar. 2020); Central Bureau of Statistics, Nepal
Vehicle fleet (stock, sales, technology shares)	Transport Management Office, Bagmati Province
Vehicle operations (mileage, load factors, fuel economy, maintenance)	Sajha Yatayat
Charging infrastructure	Sajha Yatayat
Vehicle emission standards	Ministry of Physical Infrastructure and Transport (MoPIT)
Fuel quality standards	MoPIT
Safety (accidents, security incidents)	Central Bureau of Statistics, Nepal
User perceptions (suitability for climate changes, comfort, drivability, chargeability, safety, personal security and transhipment quality)	DTU; Wuppertal Institute; UEMI; Clean Air Asia
Vehicle conversions (technical specifications, cost structures, productivity)	Sajha Yatayat; Local innovator/SME
General responsibility	DTU; Wuppertal Institute; UEMI

Table 4. Stakeholders/institutions involved in data provision and collection

2.3. VALUE FUNCTIONS

As explained in the methodology section of D1.6 – Vol.1 (Section 2.1.3.2), the KPI values estimated as described in Section 2.2 need to be transformed into star values to become compatible. This is done through value functions, which, in the case of Kathmandu, were constructed together with local stakeholders at a purposely organised workshop held in Kathmandu on 23 Nov. 2022.

There are KPIs that do not require a value function. They fall into two categories. The first one concerns the KPIs that use a 5-point scale for scoring through direct rating, in which case the KPI value is identical to the corresponding star-value. The following indicators belong to this category[5]:

- availability of financial resources (A2),
- all three institutional/political KPIs (B1, B2, and B3),
- effect on noise (D3),
- effect on environmental resources (D4),
- effect on accessibility – freight (E2), and
- all KPIs related to service quality excluding drivability as perceived by end users (E12-E19 excl. E15)

The second category consists of KPIs that were considered irrelevant for the Kathmandu demo by the participants of the stakeholder workshop, hence, requiring no value function. This category consists of the:

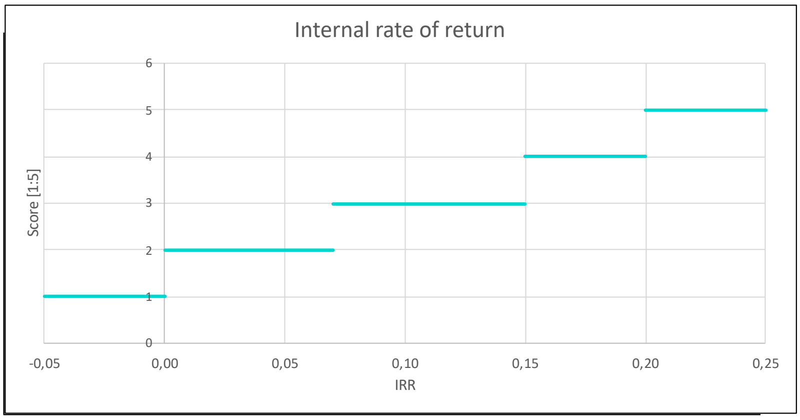
- effect on accessibility – passengers (E1), as three of the four passenger vehicles (converted bus, remodelled and new e3 wheelers) will serve at the existing public transport network replacing older vehicles, while the fourth one (newly designed shuttle van) will replace existing taxi services
- effect on well-being through active travelling (E11), as none of the demo vehicles is expected to affect the walking or biking modes of the Kathmandu users, and
- effect on drivability as perceived by end users (E15), as all demo vehicles are driven by professional drivers

The value functions of the remaining KPIs are presented below:

A1 – Financial viability

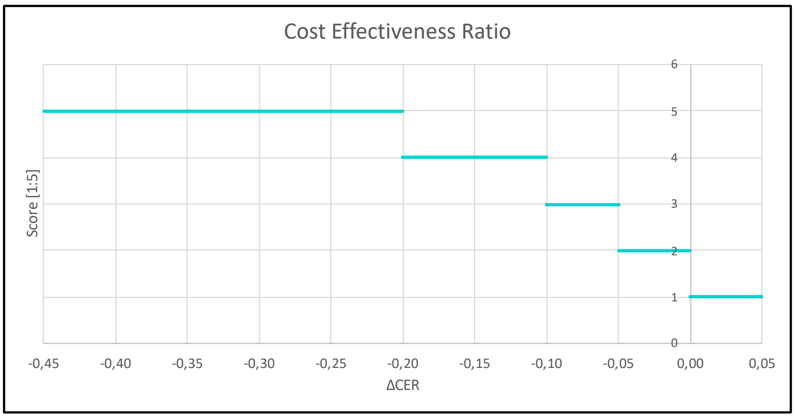
IRR, NPV and payback period are the indicators used for profit maximising operations, among which, the first two are considered more formal and are usually required by the financing institutions. Compared to NPV, IRR exhibits the advantage of being independent from the size of the investment. It was, 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 8. On the other hand, the cost effectiveness ratio (CER) is used for cost minimising operations. 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 9.

5 The numbers in parenthesis refer to the KPI numbering of Fig. 4 (Level 3).



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

Figure 8. Value function for the IRR



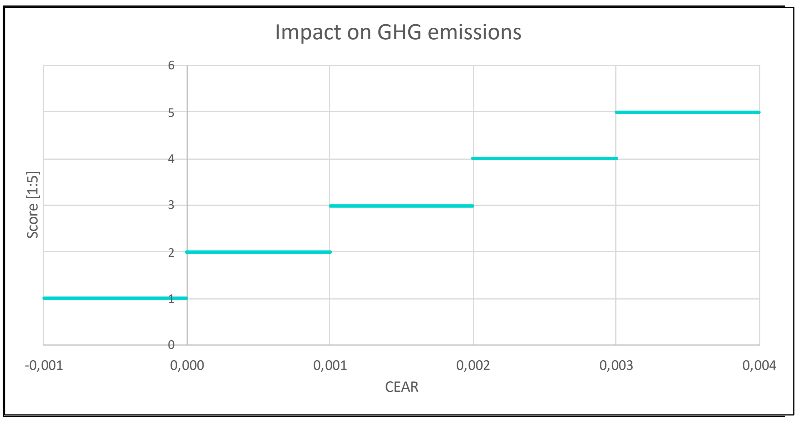
1 star	ΔCER ≥ 0%
2 stars	-5% ≤ ΔCER < 0%
3 stars	-10% ≤ ΔCER < -5%
4 stars	-20% ≤ ΔCER < -10%
5 stars	ΔCER < -20%

ΔCER: Percentage difference in CER values

Figure 9. Value function for the CER

C1 – 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). It concerns well-to-wheel CO2 emissions accumulated over the entire assessment period (2024 to 2030). The value function needed to transform the percentage change of CO2 emissions into a star value appears in Figure 10.



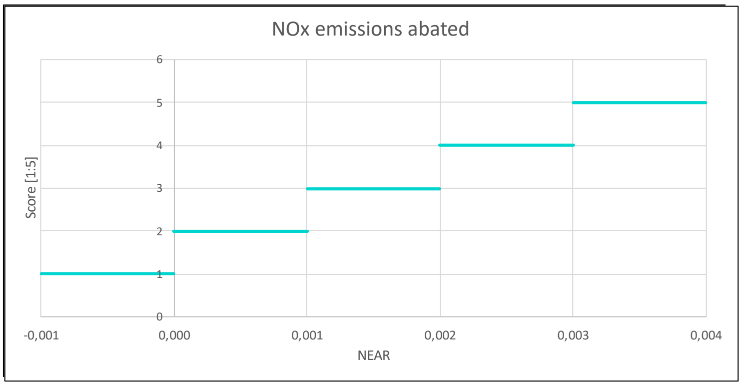
1 star	CEAR ≤ 0%
2 stars	0% < CEAR ≤ 0.1%
3 stars	0.1% < CEAR ≤ 0.2%
4 stars	0.2% < CEAR ≤ 0.3%
5 stars	CEAR > 0.3%

CEAR: Carbon Emissions Abatement Ratio

Figure 10. Value function for the effect on GHG emissions

D1 – Effect on NOx emissions

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). It concerns tank-to-wheel NOx emissions accumulated over the entire assessment period (2024 to 2030). The value function needed to transform the percentage change of NOx emissions into a star value appears in Figure 11.



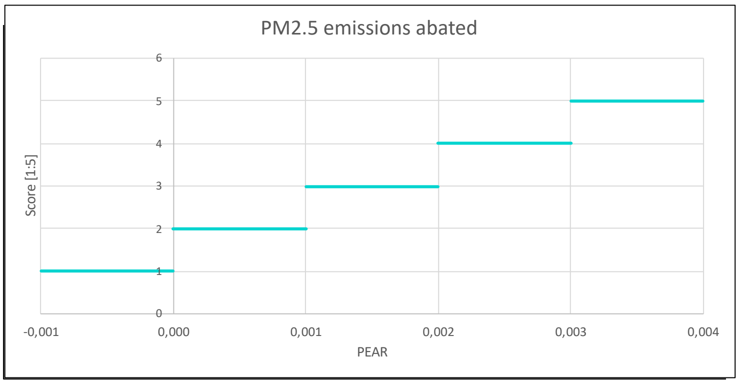
1 star	NEAR ≤ 0%
2 stars	0% < NEAR ≤ 0.1%
3 stars	0.1% < NEAR ≤ 0.2%
4 stars	0.2% < NEAR ≤ 0.3%
5 stars	NEAR > 0.3%

NEAR: Nitrogen Emissions Abatement Ratio

Figure 11. Value function for the effect on NOx emissions

D2 – Effect on PM2.5 emissions

This KPI is defined as the percentage change in the absolute mass of PM2.5 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). It concerns tank-to-wheel PM2.5 emissions accumulated over the entire assessment period (2024 to 2030). The value function needed to transform the percentage change of PM2.5 emissions into a star value appears in Figure 12.



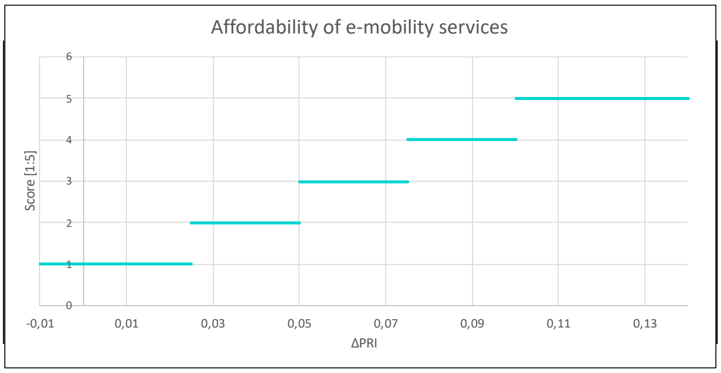
1 star	PEAR ≤ 0%
2 stars	0% < PEAR ≤ 0.1%
3 stars	0.1% < PEAR ≤ 0.2%
4 stars	0.2% < PEAR ≤ 0.3%
5 stars	PEAR > 0.3%

PEAR: $PM_{2.5}$ Emissions Abatement Ratio

Figure 12. Value function for the effect on PM2.5 emissions

E3 – Effect on affordability

This KPI is defined as the percentage change in the average unit price of the e-mobility services (ΔPRI) that the potential targeted users must pay. It is based on the average price per passenger-kilometre or price per ton-kilometre (for passenger or freight services respectively) of the new e-mobility solution as compared to the dominant or typical existing solution. The value function needed to transform ΔPRI into a star value appears in Figure 13.



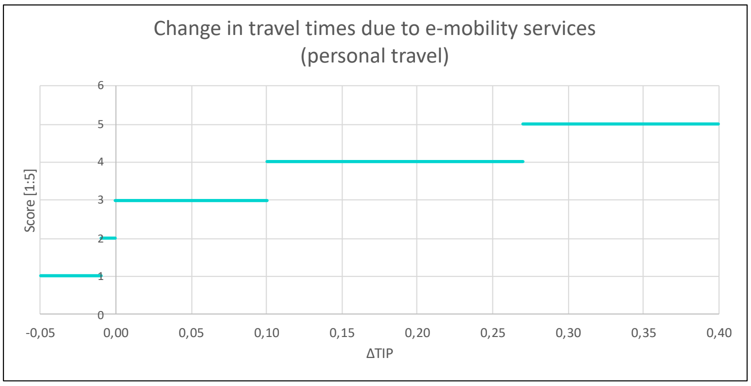
1 star	ΔPRI ≤ 2.5%
2 stars	2.5% < ΔPRI ≤ 5%
3 stars	5% < ΔPRI ≤ 7.5%
4 stars	7.5% < ΔPRI ≤ 10%
5 stars	ΔPRI > 10%

ΔPRI: Percentage difference in price per unit of transport work

Figure 13. Value function for the effect on affordability

E4 – Effect on travel time – passengers

This KPI is defined as the percentage change in average travel time (ΔTIP; expressed in minutes) between the assessed e-mobility service and the existing solution calculated on a predefined 'typical route' in the city. The value function needed to transform ΔTIP into a star value appears in Figure 14.



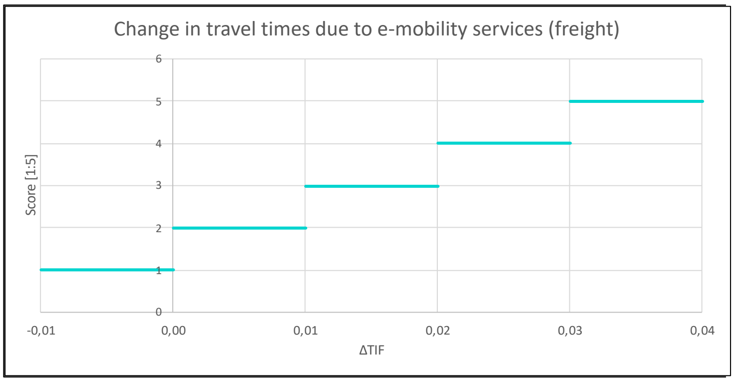
1 star	ΔTIP ≤ -1%
2 stars	-1% < ΔTIP ≤ 0%
3 stars	0% < ΔTIP ≤ 10%
4 stars	10% < ΔTIP ≤ 27%
5 stars	ΔTIP > 27%

ΔTIP: Percentage difference in travel time (passengers)

Figure 14. Value function for the effect on travel time (personal travel)

E5 – Effect on travel time – freight

Similar to E4, this KPI is defined as the percentage change in average travel time (ΔTIF; expressed in minutes) between the assessed e-mobility service and the existing solution calculated on a predefined 'typical route' in the city. The value function needed to transform ΔTIF into a star value appears in Figure 15.



1 star	ΔTIF ≤ 0%
2 stars	0% < ΔTIF ≤ 1%
3 stars	1% < ΔTIF ≤ 2%
4 stars	2% < ΔTIF ≤ 3%
5 stars	ΔTIP > 3%

ΔTIF: Percentage difference in travel time (freight)

Figure 15. Value function for the effect on travel time (freight)

E6-8 – Effect on road safety

These three KPIs – effect on major accidents (E6), effect on minor accidents (E7), and effect on vulnerable road users (E8) – are defined as the expectations of an expert group on the potential effect of the proposed up-scaled project (in terms of the corresponding type of road accidents) when compared to the situation before the implementation. Given that a 7-point scale is used for scoring these KPIs, a function is needed to transform scores into the 5-point scale of the evaluation framework. As this is a mathematical transformation, this specific function has not been discussed with the local stakeholders. The common function used for all these KPIs is shown in Table 5.

5-point scale	7-point scale
1	1,00 < Score ≤ 1,75
2	1,75 < Score ≤ 3,25
3	3,25 < Score ≤ 4,75
4	4,75 < Score ≤ 6,25
5	6,25 < Score ≤ 7,00

Table 5. Scale conversion for the road safety KPIs

E9 – Effect on charging safety incidents

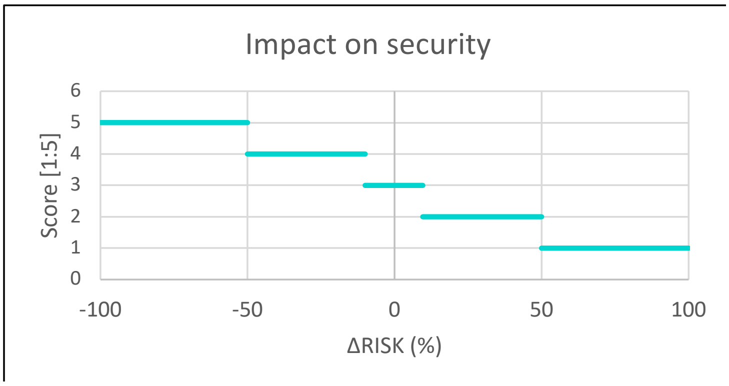
This KPI is defined as the risk associated with three different hazard categories (electrical shock, fire hazards, and power grid instability) as assessed by experts considering both the likelihood of occurrence and the potential severity. The highest risk score (defined as the product of impact with probability) among the three hazard categories is the score (RISK) of the solution under consideration. RISK is transformed into a star value through the function of Table 6. As this is basically a mathematical transformation, this specific function has not been discussed with the local stakeholders.

1 star	**RISK ≥ 12.5**
2 stars	**6.5 ≤ RISK < 12.5**
3 stars	**2.5 ≤ RISK < 6.5**
4 stars	**0.5 ≤ RISK < 2.5**
5 stars	**RISK < 0.5**

Table 6. Conversion of risk score into a star value

E10 – Effect on security incidents

This KPI is defined as the risk associated with four different Performance Standards (PS1: Infrastructure and operation, PS2: Vehicles, PS3: Transport of goods, and PS4: Transport of persons) as assessed by experts considering both the potential impact (severity/scale) and probability (likelihood of occurrence). Note that the inclusion of PS3, PS4 or both in the assessment depends on the type of vehicle/service being assessed. The highest performance score (defined as the product of impact with probability) among the applicable performance standards is the score (RISKNEW) of the solution under consideration. The same assessment is repeated for the corresponding old solution and RISKOLD is assessed. The difference between these two scores [ΔRISK=(RISKNEW-RISKOLD)/RISKOLD], expressed as a percentage over RISKOLD, is transformed into a star value through the value function of Figure 16.



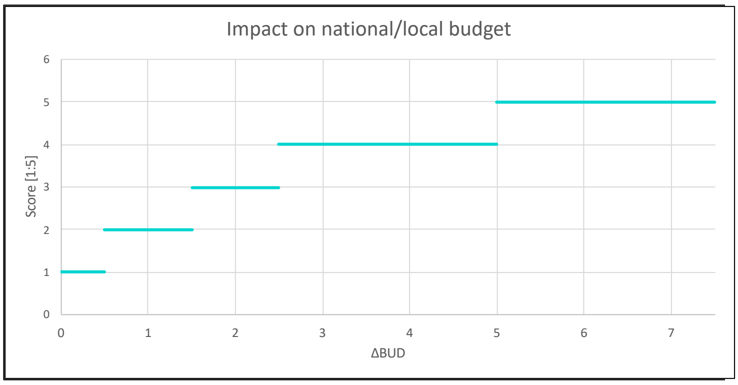
1 star	ΔRISK ≥ 50%
2 stars	10% < ΔRISK < 50%
3 stars	-10% ≤ ΔRISK ≤ 10%
4 stars	-50% < ΔRISK ≤ -10%
5 stars	ΔRISK ≤ -50%

ΔRISK: Difference in risk as a % of the risk associated with the old solution

Figure 16. Value function for the effect on security risk

F1 – Effect on national/local budget

This KPI is defined as the percentage change in the relevant (national/local) budget due to the scaled-up project. In case of funding from more than one public sources, the most burdensome effect among them will determine the KPI value (ΔBUD). The value function needed to transform ΔBUD into a star value appears in Figure 17.



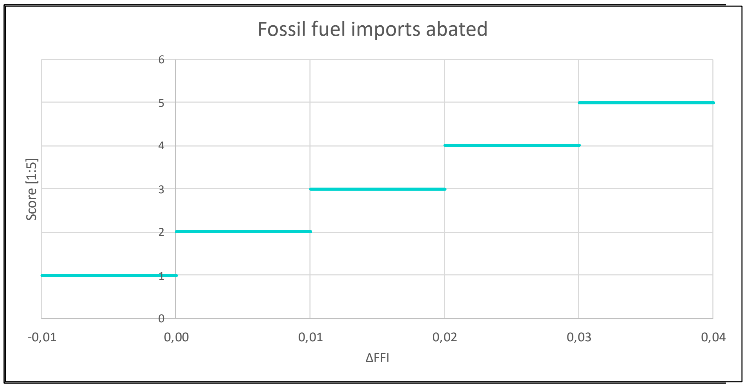
1 star	ΔBUD ≤ 0.5%
3 stars	0.5% < ΔBUD ≤ 1.5%
3 stars	1.5% < ΔBUD ≤ 2.5%
4 stars	2.5% < ΔBUD ≤ 5%
5 stars	ΔBUD > 5%

ΔBUD: Net effect on budget as a percentage of baseline scenario budget

Figure 17. Value function for the effect on national/local budget

F2 – Effect on fossil fuel imports

This KPI is defined as the percentage change in fossil fuel imports (ΔFFI) within the project area and over the project duration. The value function needed to transform ΔFFI into a star value appears in Figure 18.



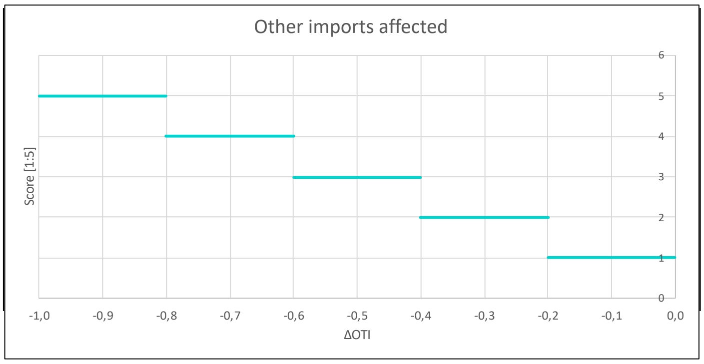
1 star	ΔFFI ≤ 0%
4 stars	0% < ΔFFI ≤ 1%
3 stars	1% < ΔFFI ≤ 2%
4 stars	2% < ΔFFI ≤ 3%
5 stars	ΔFFI > 3%

ΔFFI: Net effect on fossil fuel imports as a percentage of baseline fossil fuel imports

Figure 18. Value function for the effect on fossil fuel imports

F3 – Effect on other imports

This KPI is defined as the change in imports of the vehicles/parts of the scaled-up project when compared with the corresponding imports that would have been needed under the baseline scenario to provide the same transport services (ΔOTI). The value function needed to transform ΔOTI into a star value appears in Figure 19.



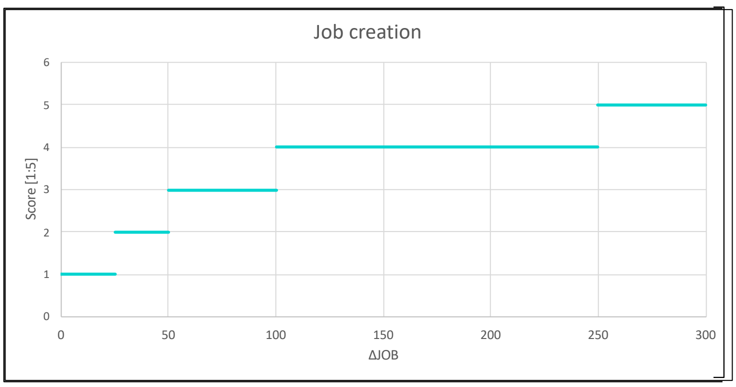
1 star	ΔOTI ≥ -0.2
5 stars	-0.4 ≤ ΔOTI < -0.2
3 stars	-0.6 ≤ ΔOTI < -0.4
4 stars	-0.6 ≤ ΔOTI < -0.8
5 stars	ΔOTI < -0.8

ΔOTI: Net effect on other imports expressed in million €

Figure 19. Value function for the effect on other imports

F4 – Effect on jobs

This KPI is defined as the absolute number of net additional jobs (ΔJOB) expected to be generated by the e-mobility solution under consideration in comparison to the baseline scenario over the entire assessment period (2024 to 2030). The value function needed to transform ΔJOB into a star value appears in Figure 20.



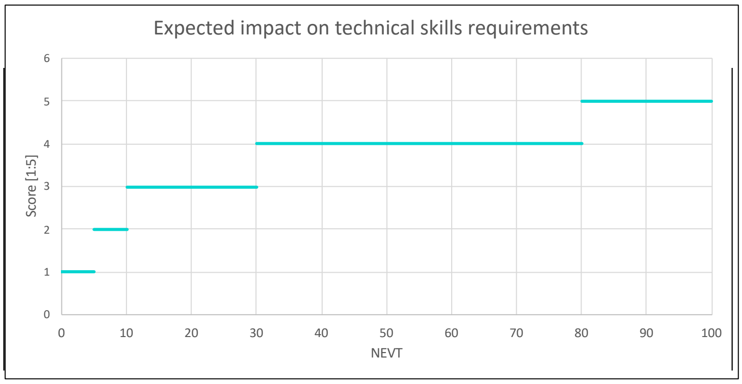
1 star	ΔJOB ≤ 20
6 stars	20 < ΔJOB ≤ 50
3 stars	50 < ΔJOB ≤ 100
4 stars	100 < ΔJOB ≤ 250
5 stars	ΔJOB > 250

ΔJOB: Net effect on added jobs

Figure 20. Value function for the effect on jobs

F5 – Effect on technical skills

This KPI is defined as the net EV technician equivalent positions (NEVT) required by the scaled-up project in comparison to the baseline scenario. All three relevant skills (EV technicians, EV design engineers, and IT analysts or other Industry 4.0 experts) are transformed into EV technician equivalent positions through the mean salaries of the respective positions in Nepal as indicated by https://www.paylab.com/ (accessed: 23/1/2024). The value function needed to transform NEVT into a star value appears in Figure 21.



1 star	NEVT ≤ 5
7 stars	5 < NEVT ≤ 10
3 stars	10 < NEVT ≤ 30
4 stars	30 < NEVT ≤ 80
5 stars	NEVT > 80

NEVT: Number of EV technician equivalent positions required

Figure 21. Value function for the effect on technical skill requirements

3 ASSESSMENT OF THE DEMONSTRATION PROJECT

The stakeholder feedback of Section 1.5 serves as a firm validation for the design of the Kathmandu demo. The knowledge exchange potential of SOLUTIONSplus is seen as pivotal in developing an e-mobility ecosystem in the city. If financially and technically feasible, the bus conversion can become a valuable option for reducing the capital cost of e-mobility in this sector, while contributing to the necessary regulatory reform. The conversion/ remodelling of smaller vehicles exhibits substantial potential in transforming urban transport. The risk associated with the intention of the new legislation to prohibit the use of 3-wheelers along the city's primary routes is real. It can be addressed, however, by the re-routing of these vehicles into secondary and tertiary routes and their integration with the main lines through appropriate applications.

This section presents the assessment of all nine components of the demonstration project in Kathmandu: the eight vehicle conversions/designs and the MaaS-related prefeasibility. Due to the contextual uniqueness of the latter one, the prefeasibility of the MaaS application will be presented first. The ex ante and ex post assessments of the remaining eight demo components will take up the rest of this section before assessing the up-scaled project in Section 4.

3.1 PREFEASIBILITY OF A MAAS APPLICATION IN KATHMANDU

The aim of this demo component is to investigate whether Kathmandu meets the necessary conditions for establishing a MaaS application including an integrated electronic payment system. The task was undertaken by two DTU students who wrote their bachelor's thesis on this subject under the supervision of the DTU staff of SOLUTIONSplus (Ortving & Brodthagen, 2022). The main findings of this work, which is based merely on literature search, are summarised here. For more details, refer to the original document.

After providing the definition of the MaaS concept and the relevant topology proposed by Sochor et al. (2018), as reproduced in Figure 22, the Whim (UK & Helsinki) application was described in detail and used as a blueprint due to its dominant position in literature.

The lessons learned from analysing Whim are:

- The analysis of traffic flows shows a much lower number of vehicles in Helsinki compared to the rest of Finland. Whilst this cannot be attributed to the introduction of MaaS itself, it can be argued that it is a direct result of having a very modern and effective public transport (PT) system in place, which served as the foundation for the MaaS application. Setting up a better PT system in Kathmandu should, therefore, be the top priority.
- Helsinki's transport operators already had Information Technology Services (ITS) in place before MaaS introduction. This allowed for a much quicker integration. Data sharing hardware, such as vehicle tracking equipment, need to be installed in all vehicles used by the participating transport operators.
- Helsinki's e-ticketing was a big success. A similar system could be implemented in Kathmandu after considering differences in the financial transaction culture of the two countries.

Figure 22. MaaS levels of integration (Source: Sochor et al., 2018)

The situation analysis of public transport in Kathmandu shows that:

- PT is bus-based but the absence of bus lanes results in very slow speeds due to severe congestion.
- Large buses cover only a very small number of routes. Smaller vehicles, such as minibuses, microbuses and 3-wheelers are, thus, a necessity.
- Buses do not always adhere to designated routes or fixed schedules. Often buses do not leave stations before being completely full. Given the short distance/duration of many trips, this renders the quicker minibuses and/or 3-wheelers preferable. Overcrowding further deteriorates the quality of service.
- There are no financial incentives for the transport operators/drivers to adhere to fixed routes, schedules or even fares. Short-term profit maximising is the rule of the game, enabled by weak enforcement of public transport and traffic regulations, as well as very low fines in case penalised.
- There is a very large number of private bus operators organised into associations of varying size and structure. This constitutes an additional challenge for a MaaS platform, requiring the cooperation of institutions such as the Federation of Nepal National Transport Entrepreneurs (FNNTE).
- Lack of pedestrian walkways and bicycle lanes leads to reduced number of trips by active transport, including bike-sharing arrangements.

In view of the above, the report concludes that:

- Under the circumstances, the establishment of a MaaS platform in Kathmandu seems presently premature. This is in line with both past failures of e-ticketing attempts and the views of local stakeholders.
- A Level 1 MaaS platform (integration of information), through an ITS application within PT, can become the initial target in this direction as soon as a framework of fixed routes/schedules/fares is put in place.
- Initially, the ITS should entail a journey planner that works across all PT classed as buses. The integration of 3-wheelers can follow on the condition that they, too, adhere to fixed routes/schedules/fares.
- Quality improvements of PT will probably require a different business model providing the proper incentives for all stakeholders involved, supported by a suitable regulatory framework.
- E-ticketing can become feasible if the following causes of past failures are adequately addressed: (i) coverage should expand to include all buses in the network, (ii) hard- and software used should be reliable resulting in a fast and secure service, and (iii) the disincentives to drivers and conductors associated with hidden cash earnings should be eliminated. As such, e-ticketing is suggested for the second stage of MaaS development.
- The fact that buses in Kathmandu account for only 28% of the daily trips, compared to the 48% share of PT in Helsinki, indicates the great potential the local public transport sector enjoys, eventually supported by a proper MaaS application.

Based on these findings, it was decided to abstain from any further pursuit of a MaaS platform in Kathmandu until a more conducive environment is put in place.

3.2. KPIS FOR ASSESSING THE DEMONSTRATION PROJECT

As mentioned in Vol.1 (Section 2.2), the demonstration project is not expected to have any impact on the wider economy due to its limited scope. As such, the last five KPIs of Figure 4 fall outside the scope of this section. For simplicity purposes, the remaining 29 KPIs have be divided into an ex ante (A1 – D2) and an ex post group (D3 – E19) (refer to Table 7). The rationale of this segregation is that the financial, institutional, and emission related KPIs of the former group can be estimated before the delivery and testing of the prototype vehicle under assessment, in contrast to the latter group of indicators that can be assessed only after a prototype becomes available. Therefore, while the ex ante assessment is limited to the first eight indicators, the ex post one needs to expand coverage through adding the 21 indicators of the second group. Note that all these 29 indicators refer to a single unit of the assessed vehicles. In contrast, the scaled-up assessment of Section 4 will refer to a project composed of several units of each demo component and will consider all 34 indicators of Figure 4.

Furthermore, the multiplicity of both the Kathmandu demo components and the assessment KPIs leads to the need to report 232 (=8x29) scores. To simplify presentation, the scores of 10 KPIs (A2, B1, B2, B3, D4, E6, E7, E8, E9, and E10) are presented tabularised for all eight components together (Section 3.3). The remaining KPIs are presented per vehicle assessed (Sections 3.4 – 3.11). Table 7 indicates the section where the respective information can be found.

Note that eight KPIs appear in Table 7 as non-applicable (N/A). In addition to E1 (passenger accessibility), E11 (active traveling), and E15 (drivability by end users), which were considered irrelevant for the Kathmandu demo by the participants of the stakeholder workshop (refer to Section 2.3), five more KPIs turned out to be irrelevant after obtaining information from the relevant end users, drivers, and experts:

- Effect on accessibility – freight (E2), as the difference in the width between the new and old solutions for all four cargo vehicles of the demo is not sufficient to influence their reach
- Effect on affordability (E3), as the financial analysis did not result in the need to increase prices. Nor can the scaled-up project be of the size needed to trigger price reductions
- Effect on travel time – passengers (E4) and – freight (E5), as the decisive parameter here is the congestion conditions of the city road network and not the vehicle speed
- Effect on transhipment quality (E19), as the services provided by the new vehicles will not alter the characteristics of transhipment (if any).

Furthermore, all KPIs related to service quality (E12-E19) of the three vehicles that have not been completed yet (new e3W design for passengers, waste collector, and shuttle van) are missing, together with those of the new e3W design for cargo, which, albeit delivered, has not received its license needed for testing the vehicle. The license of the converted bus is also missing but some testing was performed within the Sajha Yatayat depot.

			Converted bus	Remodeled Safa Tempo (passengers)	Remodeled Safa Tempo (cargo)	New e3W design (passengers)	New e3W design (cargo)	New e4W design (waste)	Converted truck	Shuttle van
Ex ante assessment	A1	Financial viability	3.4.1	3.5.1	3.6.1	3.7.1	3.8.1	3.9.1	3.10.1	3.11.1
	A2	Availability of financial resources	3.3.1	3.3.1	3.3.1	3.3.1	3.3.1	3.3.1	3.3.1	3.3.1
	B1	Coherence with national plans/goals	3.3.2	3.3.2	3.3.2	3.3.2	3.3.2	3.3.2	3.3.2	3.3.2
	B2	Alignment with legislation	3.3.3	3.3.3	3.3.3	3.3.3	3.3.3	3.3.3	3.3.3	3.3.3
	B3	Ease of implementation	3.3.4	3.3.4	3.3.4	3.3.4	3.3.4	3.3.4	3.3.4	3.3.4
	C1	Effect on GHG emissions	3.4.2	3.5.2	3.6.2	3.7.2	3.8.2	3.9.2	3.10.2	3.11.2
	D1	Effect on NOx emissions	3.4.2	3.5.2	3.6.2	3.7.2	3.8.2	3.9.2	3.10.2	3.11.2
	D2	Effect on PM emissions	3.4.2	3.5.2	3.6.2	3.7.2	3.8.2	3.9.2	3.10.2	3.11.2
Ex post assessment	D3	Effect on noise	3.4.2	3.5.2	3.6.2	3.7.2	3.8.2	3.9.2	3.10.2	3.11.2
	D4	Effect on environmental resources	3.3.5	3.3.5	3.3.5	3.3.5	3.3.5	3.3.5	3.3.5	3.3.5
	E1	Effect on accessibility - passengers	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	E2	Effect on accessibility - freight	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	E3	Effect on affordability	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	E4	Effect on travel time - passengers	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	E5	Effect on travel time - freight	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	E6	Effect on major accidents	3.3.6	3.3.6	3.3.6	3.3.6	3.3.6	3.3.6	3.3.6	3.3.6
	E7	Effect on minor accidents	3.3.7	3.3.7	3.3.7	3.3.7	3.3.7	3.3.7	3.3.7	3.3.7
	E8	Effect on accidents involving VRUs	3.3.8	3.3.8	3.3.8	3.3.8	3.3.8	3.3.8	3.3.8	3.3.8
	E9	Effect on charging safety	3.3.9	3.3.9	3.3.9	3.3.9	3.3.9	3.3.9	3.3.9	3.3.9
	E10	Effect on security	3.3.10	3.3.10	3.3.10	3.3.10	3.3.10	3.3.10	3.3.10	3.3.10
	E11	Effect on well-being (active travel)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	E12	Suitability for adverse weather	N/A	3.5.3	3.6.3	N/A	N/A	N/A	N/A	N/A
	E13	Perceived comfort	3.4.3	3.5.3	3.6.3	N/A	N/A	N/A	3.10.3	N/A
	E14	Perceived drivability (prof. drivers)	3.4.3	3.5.3	3.6.3	N/A	N/A	N/A	3.10.3	N/A
	E15	Perceived drivability (end users)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	E16	Perceived chargeability	3.4.3	3.5.3	3.6.3	N/A	N/A	N/A	3.10.3	N/A
	E17	Perceived safety	3.4.3	3.5.3	3.6.3	N/A	N/A	N/A	3.10.3	N/A
	E18	Perceived personal security	N/A	3.5.3	3.6.3	N/A	N/A	N/A	N/A	N/A
	E19	Perceived transhipment quality	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 7. Applicable KPIs and corresponding report sections

3.3. GROUPED INDICATORS

This section presents in tabular form the rating of each demo component against the parameters that enter the definition of 10 composite KPIs, as well as the corresponding final score. The justification of each rating is provided through the explanatory notes shown in the lower part of each table. The links to supporting documents are also provided.

The scores on the availability of financial resources (Section 3.3.1) range between 2 and 5. The highest score is achieved by the remodelled and newly designed e3W for passenger services due to the possibility of obtaining entrepreneurship loans offered by commercial banks to female owners of such vehicles.

According to Section 3.3.2, all components are fully coherent with the national plans and development goals. Although this finding is comforting regarding the selection of the demo components, it actually nullifies this KPI since all alternative scaled-up projects will have an identical score. The common uncertainties that all components face relate to the lack of technical standards and working guidelines/directives that convert the national strategies into specific actions (Section 3.3.3). The conditions stipulated by the directive on vehicle conversions are of interest to the bus and truck conversion activities of the demo, while investments in light public transport passenger vehicles are challenged by the remnants of the syndicate system that has been formally abolished. In relation to implementation issues (Section 3.3.4), it appears that the necessary political and institutional bodies are in place and the required interventions (of limited scope) are already ongoing/planned. However, the frequent changes and transfer of officials at the Ministry of Physical Infrastructure and Transport (MoPIT) and the Department of Transport Management (DoTM) slows the process.

The effect on environmental resources (Section 3.3.5) was assessed by the project team and confirmed with five transport experts affiliated with DoTM (1 expert), ADB (1 expert), and the Kathmandu University (3 experts). It appears that the converted and remodelled vehicles achieve a high score due to the remanufacturing activities and the opportunities for recycling that they offer. On the contrary, the new designs score low as the manufacturing processes still rely on conventional practices and the vehicles lack smart features that could contribute to more efficient and sustainable operations. The recycling of the battery is a possibility which, however, needs to be pursued at national level, as presently there is no such infrastructure, and batteries are either improperly dumped or exported to India (GGGI, 2018a). The expansion of e-mobility in the country will benefit from such an investment through the availability of recycled by-products locally in addition to the reduction of pollution caused by the improper disposal of used batteries.

The three KPIs concerning road safety (Sections 3.3.6 to 3.3.8) are assessed through interviews with the same five transport experts mentioned above. According to the KPI definition (Appendix B, Vol.1), a 7-point scale was used for scoring. The average score among the five interviewees[6] was then converted into a 5-point-scale score through the transformation function of Table 5. The experts made no distinction between major and minor accidents (E6 & E7). For these two KPIs, the converted vehicles (bus and trucks) are expected to lead to a slight improvement over the old solutions due to lower probability of mechanical failures. No change is expected for the e3Ws, while the shuttle van lies in between. In relation to accidents involving VRUs (E8), none of the demo vehicles is expected to have an influence on average, as one of the experts anticipates improvement due to the better drivability of EVs, one expects deterioration due to their lower intensity noise, while the others see no foreseeable change.

The risk of accidents related to the charging of EVs is expected to grow with the proliferation of e-mobility. The lack of institutionalised standards in the country can aggravate this risk. The formal standardisation of the locally produced EVs is expected

6 The responses of only three interviewees were considered for E8 (accidents involving VRUs), since two responses had to be discarded as irrelevant (compared safety performance across components rather than benchmarking against the respective old solutions).

to reduce this risk in addition to facilitating consumer trust. The five experts who offered their opinion on road safety were also interviewed for this type of hazards (refer to Section 3.3.9). Electrical shock exhibits the highest risk for the converted and remodelled vehicles due to moderate severity but also moderate likelihood of occurrence, as these vehicles may be more prone to equipment malfunctions or human errors during maintenance/repairs. The new designs are expected to suffer more by instability in the power grid, which, despite minor/low impact, occurs frequently in Nepal due to intermittent power supply and voltage fluctuations.

The KPI on security is assessed by three experts in total, two of which are transport operators, the third being affiliated with DoTM (Section 3.3.10). The general conclusion is that the security challenges are driven mostly by exogenous factors such as the socio-economic conditions, political environment, and geographical aspects rather than the type of vehicles. The security risks concerning passenger vehicles are much higher than those of the freight ones. However, when the experts were asked to compare the new solutions with the corresponding old ones, they were not able to detect a difference, giving the same score to all demo components.

3.3.1. AVAILABILITY OF FINANCIAL RESOURCES

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	

Notes		Link(s)	
[1]	The Council of Ministers of the Federal Government on 14 July 2019 decided to invest € 22.7 million to Sajha Yatayat for the procurement of electric buses [OPMCM, 2019].	Link	
[2]	The governments of the Bagmati province, the Kathmandu Metropolitan City, and the Lalitpur Metropolitan City decided to provide € 3.37 million to Sajha Yatayat for procuring electric buses in the Valley [MoEAP, 2021 and The Himalayan Times, 2021]	Link	Link
[3]	The Bagmati Province Government has allocated € 1.5 million to install charging stations in different locations of the province targeting urban areas and highways [Republica, 2022].	Link	
[4]	Through the fiscal budget 2022/23 (MoF, 2022), the federal GoN has adopted a policy of phasing-out light duty fossil fuel vehicles and switching to electric ones by 2031. It also includes a plan to build 500 charging stations throughout the country in a year, give renewal and road tax exemption for 5 years to vehicles that have been converted from internal combustion engines to electric, operate a minimum of 100 electric buses in the Kathmandu Valley, and provide financial support to develop electric public transportation. This year's budget speech has provision for promoting government and private owners for purchasing EVs, electric public transports and charging stations, while no fossil fuel vehicles will be purchased for Government entities. Furthermore, it opens the way for converting ICE to EV and allocates funds for the establishment of 50 charging stations. Electric vehicle assembling factory to get 40% tax deduction for 5 years.	Link	
[5]	The Asian Development Bank, Global Environmental Facility and the GoN invested € 28.4 Million for the Kathmandu Sustainable Urban Transport Project which was completed in 2018. Although not materialized, the procurement of electric buses was a project component.	Link	
[6]	Funds like GCF, GEF, Adaptation fund (developing sustainable transportation infrastructure project etc.), GGGI, WWF can be available. TDF (Town Development Fund) is planning to help KMC (Kathmandu Municipal Corporation) in expanding electric bus service (Nepalnews, 2022).	Link	
[7]	The introduction of safa tempos was funded by US-AEP/NASDA, USAID/Nepal, and US-AEP.	Link	
[8]	The Standard Chartered Bank and Aeloi Technologies are collaborating to provide entrepreneurship loans to female safa tempo owners. The loan will be provided by the Standard Chartered Bank Nepal and subsidized by the Government of Nepal .	Link	
[9]	Nepal Action plan for electric mobility (MoPIT, 2018) has planned to establish a national subsidy scheme for electric mobility. However, it has not been enforced yet .	Link	
[10]	NDC 2020 includes statements promoting public electric mobility through policy incentives, including subisdy policies and other financial mechanisms, which, however, have not been enforced as of now through proper directives	Link	
[11]	In the case of e-shuttle vans, no financing was ever been made available in the past. Neither is any today.		

3.3.2. COHERENCE WITH NATIONAL PLANS AND DEVELOPMENT GOALS

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**	

Notes		
[1]	The objectives of the **National Transport Policy (MoPIT, 2002)** is to establish a sustainable transport system in Nepal. The policy plans to operate bus, tram and other vehicles powered by electricity and solar power.	Link
[2]	The **Environment Friendly Vehicle and Transport Policy (MoPIT, 2014)** aims to reduce emission from transport sector, increase the share of electric vehicle and promote the transformation of other regular vehicle to electric vehicle, and provide a subsidy scheme for the promotion of electric vehicles and non-motorised transport modes.	Link
[3]	**Quality, operation and management standard of public vehicles (MoLET, Bagmati Province, 2022)** (except taxis) has set up criteria for operation and transfer of number plates from old vehicles. Old public vehicles can be replaced with EVs under the same number plate.	Link
[4]	The main objective of the **National Sustainable Transport Strategy for Nepal (2015-2040) (UNCRD, 2015)** is to develop a transport system that is efficient, accessible, people-centric, affordable, reliable, safe, inclusive, environmental friendly, and climate and disaster resilient. This document plans to increase the mode share of public transport and the percentage of electric vehicle in the total fleet. The strategy considers introduction of trolley buses or electric buses in Kathmandu and other urban areas of Nepal as areas of strategic importance in the transport sector. It also suggests the introduction of electric rickshaws in small and medium cities, albeit without mentioning the conversion possibility explicitly; it does not prohibit it either.	Link
[5]	The **National Energy Efficiency Strategy of Nepal (MoEWRI, 2018)** plans to improve the energy efficiency of the transport system by targeting the consumers of transport sectors. It aims to reduce the sector's air pollution and GHG emissions by promoting the use of energy efficient equipment. It emphasises on the usage of electric vehicles and public transport.	Link
[6]	The **Kathmandu Valley Air Quality Mgmt Action Plan (MoFE, 2019)** defines the strategic priority areas among which, "mitigation of emissions from vehicles" and "promotion of environmentally sustainable transportation system" are specific to the transport sector. Under these areas, the plan foresees vehicle upgrading, setting of vehicle emission standards, formulating fuel economy standards, establishing charging infrastructures for electric vehicles, and introducing legal provision for converting old vehicles into electric vehicles among others.	Link
[7]	The **Second Nationally Determined Contribution (GoN, 2020)** prioritizes the transport sector and sets targets focusing on the sales of electric vehicles and the reduction of the dependency on import of petroleum products. The target has been set for the sales of public electric 4-wheeler passenger vehicles to 20% by 2025, and 60 % by 2030 of total vehicles (excluding electric rikshaws and electric tempos).	Link
[8]	The **National Climate Change Policy of Nepal (DoEnv, 2019)** adopts sectoral policies including for the transport sector. Developing reliable, sustainable and low carbon technology in the transport sector, development and implementation of mitigation standards, identifying the key cause of emissions in transport sector, introduction of energy efficient technologies in the transport sector, use of electric vehicles, encouragement and mobilisation of private sector for the reduction of emission from the transport sector, and phasing out of vehicles that have exceeded certain years of running period are some of the policies, which are beneficial to bus convertion, 3 wheelers , e-shuttle van and truck conversion.	Link
[9]	The board meeting of **Nepal Electricity Authority in January 2022** revised the distrubtion bylaws and decided to install separate metres at public places and parking lots to charge EVs. Installation will be made by the state-owned utility. This is in line with the governments' aim of increasing the consumtpion of electricity, but will benefit both public and private EVs.	Link
[10]	**Nepal's Third National Communication to the UNFCCC (MoFE, 2020)** announces the formulation of a new National Transportation (Vehicle) Policy, which will encourage the importing and manufacturing of environment-friendly and low-pollutant vehicles in Nepal.	Link
[11]	**Nepal's Sustainable Development Goals Status and Roadmap: 2016-2030 (UNDP, 2018):** Although not mentioning EVs specifically, the Government of Nepal targets increasing the share of public transport system to 50 % of total trips by the year 2030. Nevertheless, increasing public vehicles' share could benefit bus convertion, 3 wheelers and E-shuttle van.	Link

3.3.3. ALIGNMENT WITH SUPRA-NATIONAL/NATIONAL/CITY LEGISLATION & REGULATIONS

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	

Notes		
[1]	**Vehicle & Transport Managemnet Act, 2049 amendment (MoPIT, 2078)** has opened up the possibility of converting ICE to EVs but in absence of the relevant directives and the delay in their formulation, there is uncertainty concerning implementation.	Link
[2]	**Environment Friendly Vehicle and Transport Policy (MoPIT, 2014)** plans to regulate the provision of electric vehicle standards, and places the provision for the conversion and associated matters of different types of vehicles under the leadership of the Department of Transport Management. However, the guidelines and/or standards have not been formulated yet. Currently, MoPIT is revising the Transport Act, which is expected to incorporate the conversion of ICE to EVs and promote EVs and public transportation [Interview with Shankhar Dhami, Under-secreatary of MoPIT].	Link
[3]	**National Energy Efficiency Strategy of Nepal (MoEWRI, 2018)** plans to promote the use of energy efficient equipment and initiate energy efficiency in transport sector. However, in the absence of working guidelines and relevant directives, there is uncertainty concerning its implementation and effectiveness.	Link
[4]	The syndicate system is formally abolished in Nepal. However in practice, there are some challenges for small scale investors willing to invest in public transport, affecting the introduction of e-mobility in public transportation **(THT, 2022)**	Link

3.3.4. EASE OF IMPLEMENTATION (IN TERMS OF ADMINISTRATIVE BARRIERS)

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	

Notes		
[1]	**Vehicle & Transport Managemnet Act, 2049 amendment (MoPIT, 2018)** has opened up the provision of conversion of ICE to EVs but in absence of directives, the ease of implemention at the moment is questionable. Currently, MoPIT is revising the Transport Act, which is expected to incorporate the conversion of ICE to EVs and promote EVs and public transportation [Interview with Shankhar Dhami, Under-secreatary of MoPIT].	Link
[2]	**Environment Friendly Vehicle and Transport Policy (MoPIT, 2014)** plans to formulate a guideline/standard which is expected to define the provision for electric vehicle standard, set the provision for different types of vehicle conversion and associated matters under the leadership of Department of Transport management but is yet to be formulated.	Link
[3]	The **MoPIT** is the focal ministry for the transport sector and the **DoTM** is mandated to manage transport management in Nepal at federal level. The **Province Transport Directorate** under MoPID of the Bagmati Province is responsible for managing transport management and building infrastructure at the Bagmati Provincial level. There are adequate policies and acts in the transport sector at both federal and provincial level, however these lack guidelines, directives and standards for effective implementation.	
[4]	**The Kathmandu Valley Public Transport Authority Infrastructure Development Board** was established as per the Valley Public Transport Management Authority Act-2019, which is expected to coordinate and provide effective management of public transport in collaboration with all three tier of the Government of Nepal (**THT, 2019**)	Link
[5]	Contrary to the 2017 elections, all major political parties (Nepali Congress, UML, Maoist etc) had included the promotion of EVs and the strengthening of public transportation in Nepal in the federal and provincial campaigns for the 2022 elections **(NN, 2022).** However, the frequent changes and transfer of officials at the Ministry and the DoTM slows the process.	Link

3.3.5. EFFECT ON ENVIRONMENTAL RESOURCES

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.								

3.3.6. EFFECT ON MAJOR ACCIDENTS

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]

3.3.7. EFFECT ON MINOR ACCIDENTS

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]

3.3.8. EFFECT ON VULNERABLE ROAD USERS

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]

3.3.9. EFFECT ON CHARGING SAFETY

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**

Notes	
[1]	The converted vehicles operate on an electrical power system that includes high-voltage components such as batteries and charging infrastructure. While these components are designed with safety features, there is still a possibility of electrical incidents occurring. Potential reasons include occasional equipment malfunctions, human errors during maintenance/repairs, or external factors like extreme weather conditions or electrical grid fluctuations. For this type of vehicles, two experts assessed the likelihood of occurrence as moderate (once per year), two as high (once per month) and one as low (less than once per 5 years). For the remodelled e3Ws, all experts assessed this likelihood as moderate. On the contrary, the new designs use advanced electrical systems and components, including batteries, motors, and wiring. Most likely, these vehicles will undergo thorough testing and comply with safety standards, reducing the chances of electrical incidents. For the new e3W designs four experts assessed the likelihood of occurrence as low, and one as very low (less than once per 10 years). For the new shuttle van, three experts assessed it as low and two as very low.
[2]	Electric shocks have the potential to cause significant harm to individuals including burns, muscle contractions, and even potential cardiac disturbances. None of the experts identified any difference among the various components. Three experts assessed severity as moderate, one as low and one as high.
[3]	The design, construction, and safety measures implemented in the vehicles, as well as adherence to existing standards and regulations, effectively minimise the chances of fire incidents. For the converted vehicles, three experts assessed the likelihood of occurrence as low (less than once per 5 years) and two as moderate (once per year). For the remodelled e3Ws and the shuttle van all experts assessed this likelihood as low. For the new e3W designs, all experts assessed it as low, with the exception of one who expected it to be very low (less than once per 10 years).
[4]	The fire incidents can have significant adverse impacts including extensive damage to the vehicle itself, potential injuries to occupants or bystanders, and the risk of fire spreading to nearby structures or environments. Three experts assessed severity as high, and two as moderate.
[5]	Intermittent power supply and voltage fluctuations cause frequent power grid instability and occasional blackouts in Nepal. All experts assessed the likelihood of occurrence as high (once per month).
[6]	To mitigate the effects of power fluctuations, all vehicles have implemented measures such as voltage regulation and surge protection, and are equipped with robust electrical components. For the converted vehicles, three experts expect a low impact and two a minor one. For the remaining demo components, only one expert foresees a low impact, all others expecting only a minor one.

3.3.10. EFFECT ON SECURITY

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.

3.4. BUS CONVERSION

3.4.1. FINANCIAL VIABILITY

The output of this component is an e-bus that results from converting an old diesel-powered vehicle through installing an electric drive system (motor, transmission, and rear axle) on the existing chassis. The conversion was performed locally using imported components and took the following conditions into consideration:

- the local topographical conditions (road gradient of max 10°)
- the local climatic conditions (avg. temperature min 2˚C to max 30˚C, 110 rainfall days, 1,450mm)
- the functional needs (about 100 km per day

Once properly licensed, the converted e-bus will be operated on one of the current Sajha Yatayat routes (Lagankhel to Budhanilkantha) with a round-trip length of 32 km. After comparing a number of operating schemes concerning daily operating hours and the corresponding charging time, it was decided to perform 3 roundtrips per day transporting in total 366 passengers daily. This can be achieved with about 7 hours of overnight charging at the Sajha depot plus 1.5 hours of opportunity charging in one of the terminal stops of the route. The expected energy consumption is 0.56 kWh/km in the first year of operation, gradually increasing to 0.93 kWh/km by Year 10 (due to efficiency losses of the battery).

Demonstration scale

Table 8 presents the input values entering the calculation of the financial indicators at demonstration scale seen from the perspective of Sajha Yatayat, which undertook the conversion in their own workshop at an estimated cost of 8.5 million NPR (including the purchase of the old diesel bus). A declining balance depreciation of 10% per year applies, as well as a flat income tax rate of 25%.

Converted bus - Demonstration scale - Input values				
Category	**Parameter**	**Value**	**Units**	**Comments**
General info	Year converted	2023		
	Passenger capacity	50		
Propulsion	Battery type	LFP		
	Battery size (set)	56	kWh	
	Number of batteries in set	3		
Capital cost	Investment cost	8.507.500	NPR	
	* Purchase price	8.500.000	NPR	Includes purchase of old bus
	* Charging infrastructure	0	NPR	
	* Training cost	5.000	NPR	
	* Public Number Plate	2.500	NPR	
	Expected useful life	10	years	
	Residual value	1.180.000	NPR	Residual value of bus and battery
	Depreciation schedule	10%		Per year
Operational profile	Route	Lagankhel to Budhanilkantha		
	Length of round trip	32	km	
	Round trips/day	3	trips/day	
	Total distance/day	96	km/day	(=3*32)
	Operating days/year	326	days/year	
	Passengers/day	366	pax	
	Chargings/day	1+1		Overnight charging & opportunity charging for 1,5 h
Yearly operating	Total operating cost	994.836	NPR/year	
	* Route permit	1.600	NPR/year	
	* Vehicle road tax	8.000	NPR/year	
	* Technical inspection	1.000	NPR/year	
	* Insurance	28.000	NPR/year	
	* Personnel cost	582.000	NPR/year	Two employees @ 291.000 NPR/year each
	* Electricity cost	140.206	NPR/year	
	- Specific energy consumption	0,56	kWh/km	44,8 kWh(=80%*56) need 6,8 h for charging. By Year 10, battery's efficiency drops to 60%.
	- Electricity tariff	8	NPR/kWh	Special tariff for public transport EVs
	* Maintenance cost	234.030	NPR/year	70% of maintenance cost of new e-bus (334.328 NPR)
	* Other	0	NPR/year	
Yearly revenues	Total revenues	2.267.004	NPR/year	(=326*366*19)
	Ticket fare/passenger	19	NPR	On average
Income tax	Income tax rate	25%		

Table 8. Input values for assessing the converted bus (Demonstration scale)

Converted bus - Demonstration scale - Calculations											
Discount rate	10%										
	Y0	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
Year	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Investment	-8.507.500										
Residual value											1.180.000
Annual revenues		2.267.004	2.267.004	2.267.004	2.267.004	2.267.004	2.267.004	2.267.004	2.267.004	2.267.004	2.267.004
Annual operating & maintenance costs		-994.836	-1.003.024	-1.011.690	-1.020.862	-1.030.570	-1.040.845	-1.051.720	-1.063.230	-1.075.413	-1.088.306
Net pre-tax cash flow	-8.507.500	1.272.168	1.263.980	1.255.314	1.246.142	1.236.434	1.226.159	1.215.284	1.203.774	1.191.591	2.358.698
Cumulative pre-tax cash flow	-8.507.500	-7.235.332	-5.971.351	-4.716.037	-3.469.896	-2.233.462	-1.007.303	207.981	1.411.754	2.603.346	4.962.043
Year	0	1	2	3	4	5	6	7	8	9	10
Pre-tax NPV	-452.308										
Pre-tax IRR	8,81%										
Pre-tax payback (years)	6,83										
Depreciation		-732.000	-658.800	-592.920	-533.628	-480.265	-432.239	-389.015	-350.113	-315.102	-283.592
Book value		7.768.000	7.109.200	6.516.280	5.982.652	5.502.387	5.070.148	4.681.133	4.331.020	4.015.918	3.732.326
Taxable income		540.168	605.180	662.394	712.514	756.169	793.920	826.269	853.660	876.489	-1.657.220
Income tax		-135.042	-151.295	-165.599	-178.128	-189.042	-198.480	-206.567	-213.415	-219.122	0
Net after-tax cash flow	-8.507.500	1.137.126	1.112.685	1.089.716	1.068.013	1.047.392	1.027.679	1.008.717	990.359	972.469	2.358.698
Cumulative after-tax cash flow	-8.507.500	-7.370.374	-6.257.689	-5.167.973	-4.099.960	-3.052.568	-2.024.889	-1.016.173	-25.814	946.655	3.305.352
Year	0	1	2	3	4	5	6	7	8	9	10
After-tax NPV	-1.474.099										
After-tax IRR	6,02%										
After-tax payback (years)	8,03										

Table 9. Financial indicators for the converted bus (Demonstration scale)

The calculations are shown in Table 9. The pre-tax IRR is estimated at 8.81%, not a bad figure considering that the calculations are made in constant 2023 NPR prices. However, at a discount rate of 10%, this figure leads to a slightly negative NPV (about -450,000 NPR). The corresponding payback period is 6.83 years. Table 10 compares the bus conversion to two other alternatives of Sajha Yatayat: the purchase of a new e-bus (identical to the 3 buses recently arrived from China) and the purchase of a new diesel bus (similar to those in operation). It appears that, with the current diesel fuel prices (mean price over the period Oct.'22-Jan.'23) and an average fuel consumption of 0,22 lt/km (Das, et al., 2022), the diesel bus remains the most profitable solution due to its low acquisition cost. The converted bus is not as profitable as the new e-bus but it comes close and the investment requirements are much lower.

Parameter		Converted bus	New e-bus	New diesel bus
Size	Passenger capacity	50	60	70
Capital cost	Investment cost (NPR)	8.507.500	13.183.010	4.947.500
	Residual value (NPR)	1.180.000	3.896.681	1.482.000
Operational profile	Route	Lagankhel to Budhanilkantha		
	Round trips/day	3	4	4
	Passengers/day	366	579	684
Yearly operating cost	Total operating cost (NPR)	994.836 [1]	1.225.544 [3]	3.980.265
	* Personnel cost (NPR)	582.000	582.000	582.000
	* Electricity/fuel cost (NPR)	140.206 [2]	267.059 [4]	2.920.960
	* Maintenance cost (NPR)	234.030	334.328	418.705
	* Other (NPR)	38.600	42.157	58.600
Yearly revenues	Total revenues	2.267.004	3.586.326	4.236.696
Financial indicators (pre-tax)	NPV (@ 10% discount rate)	-452.308	2.412.601	5.276.148
	IRR	8,81%	13,75%	30,12%
	Payback period	6,83	5,68	3,15
Financial indicators (after-tax)	NPV (@ 10% discount rate)	-1.474.099	49.464	3.353.438
	IRR	6,02%	10,08%	23,02%
	Payback period	8,03	6,93	3,94
1 Reaching 1.088.306 in Year 10		3 Reaching 1.403.584 in Year 10		
2 Reaching 233.677 in Year 10		4 Reaching 445.099 in Year 10		

Table 10. Comparison of bus conversion to other alternatives

The taxation reduces profitability as expected and prolongs the payback period, which, however, remains shorter than the foreseen useful life of the vehicle (10 years).

The discount rate used in the NPV calculations is the opportunity cost of capital (returns forgone by investing in the project) and reflects the returns of a risk-free investment (long-term government bonds) plus the premium required for projects of similar risk. Since the analysis is done in real terms, the discount rate needs to be expressed in real terms, too (excluding inflation). According to Moody's Analytics, the latest long-term government bond in Nepal was issued in June 2017 at an interest rate of 6%[7]. Devkota et al. (2021) suggest a minimum discount rate for chemical plants of 10%, while an older study on an organic coffee farming project in Nepal used a discount rate of 12% (Poudel et al., 2009). Figure 23(A) presents the effects of different discount rates on the pre-tax NPV. The project exhibits positive NPV at rates lower than the IRR of 8.81%, while at a rate of 20%, losses can surmount the mark of 3 million NPR.

The cost of conversion is also a factor that can have a significant influence on the profitability of the project. Figure 23(B) shows that a conversion cost of less than 8 million NPR produces a positive NPV, enhancing the significance of possible economies of scale at a later stage of the project.

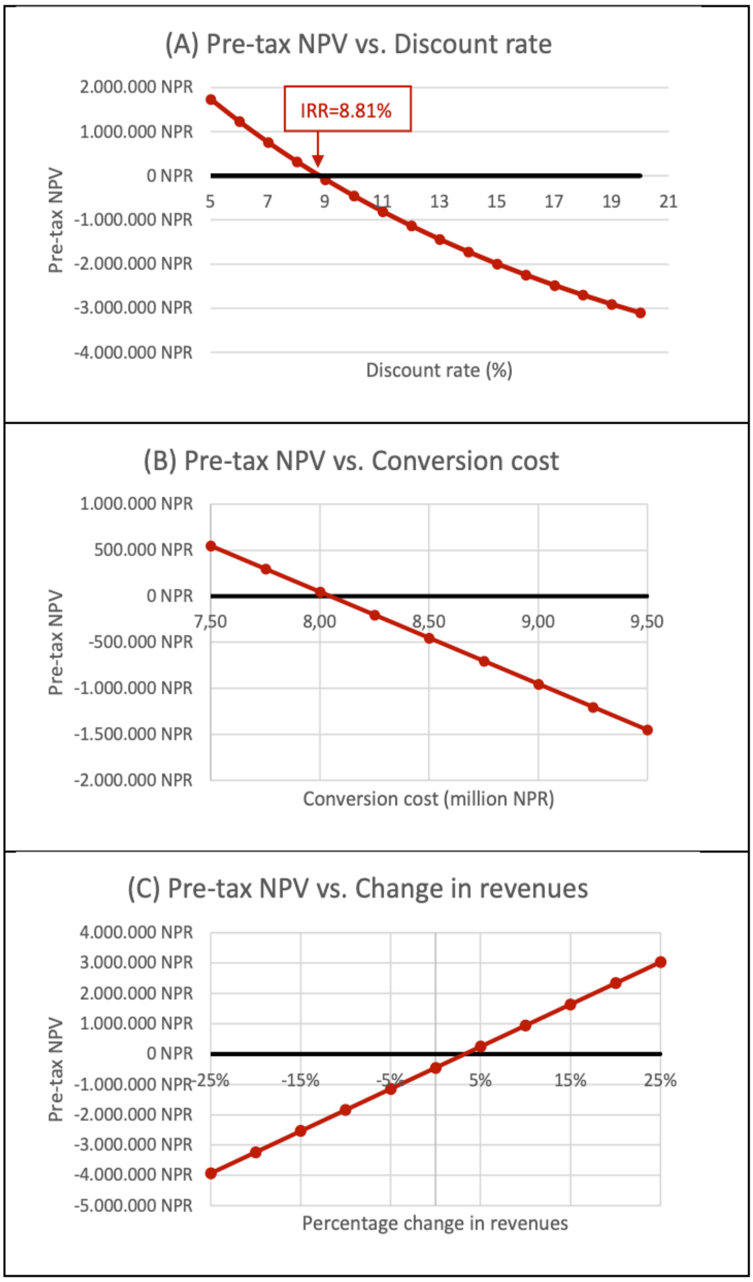


Figure 23. Sensitivity analysis of NPV in relation to discount rate (A), conversion cost (B) and change in revenues (C)

7 https://www.economy.com/nepal/average-long-term-government-bond

Expected revenues, too, is a critical factor in the profitability calculations. With a small increase of about 3% on the estimated revenues of Table 8, the NPV changes sign, while a drop in revenues can be devastating. The fact that the projected number of passengers was based on the average capacity utilisation of larger buses, though, makes the probability of a positive change higher than the opposite, since it is easier to fill up a smaller vehicle during off-pick hours.

Production scale

Although the demonstration bus will be converted at the Sajha Yatayat facilities, this will not be the case for the up-scaled production. This task is expected to be undertaken by a specialised workshop/manufacturer. Two changes in the conversion cost estimate are associated with this fact. Firstly, the conversion kits will be procured in larger quantities and a volume discount should be secured. In addition, economies of scale will result in lower production costs. In total, a 30% discount on the conversion cost is foreseen to cater for scale. Secondly, the manufacturer will have to earn a profit from this activity. A 10% profit has been added to the cost estimate as a result. Due to these adjustments, the investment cost now becomes 6.545.000 NPR. All other figures remain unaltered.

Table 11 presents the results. The financial performance of the conversion is now very close to this of the new bus. Although the pre-tax IRR value is slightly better than the new bus one, the corresponding NPV is lower due to the difference in investment cost.

Financial indicators		Converted bus	New e-bus
Pre-tax	NPV (@ 10% discount rate)	1.502.692	2.412.601
	IRR	14,86%	13,75%
	Payback period	5,23	5,68
After-tax	NPV (@ 10% discount rate)	276.677	49.464
	IRR	10,92%	10,08%
	Payback period	6,30	6,93

Table 11. Comparison of bus conversion to a new e-bus (Scaled production)

3.4.2. EFFECT ON EMISSIONS AND NOISE

GHG emissions

Along the Lagankhel-Budanilkantha route, an existing diesel bus of Sajha Yatayat travels on average 128 km daily (=4 trips of 32 km each). Assuming an average deployment of 326 days per year (=27.17 days per month), the annual mileage of a bus on this route amounts to 41,728 km. Das et al. (2022) estimate that on average the specific fuel consumption of such a bus in Kathmandu is 0.22 lt/km, leading to an annual consumption of 9,180 lt of diesel oil. This figure must be adjusted to reflect differences in transport work (due to size and round trips) performed by a demo and a diesel bus. Based on Sajha Yatayat statistics a diesel bus on the Lagankhel-Budanilkantha route serves 684 passengers daily. Assuming the same utilisation rate, the demo vehicle will serve 366 passengers per day, resulting in an adjustment factor of 0.5351. The application of this factor to the fuel consumption estimated above leads to an amount of 4,912 lt of diesel oil annually.

The tank-to-wheel (TtW) CO2 emission factor of diesel oil is 2,582 gr/lt (Das et al., 2022). According to the e-Mob calculator of UNEP, the well-to-tank (WtT) CO2 emission factor of diesel oil is 500 gr/lt, resulting in a well-to-wheel (WtW) factor of 3,082 gr/lt.

The adjusted annual fuel consumption estimated above then results into 15.14 tonnes of CO2 emissions per year. Under the assumption that all electricity used by the converted e-bus will be generated exclusively through renewable sources[8], the figure of 15.14 tonnes per year will be the expected gain in GHG due to the conversion.

NOx emissions

According to ARAI (2007), the average NOx emission factor for heavy commercial diesel buses in India, built in the period 2000-2006, is estimated at 9.02 gr/km. Assuming an average fuel efficiency for medium size buses in this country of 4.55 km/lt (Karali et al., 2019), this estimate is transformed into 40.98 gr/lt. The application of this factor on the adjusted annual fuel consumption estimated above results in a figure of 201.30 kg of NOx emissions abated annually per unit of converted bus.

PM2.5 emissions

Similarly, the PM2.5 emissions factor[9] for this type of fuel and vehicle is 10.62 gr/lt (Das et al., 2022). The mass of abated PM2.5 emissions annually per unit of converted bus then becomes 52 kg.

Noise

Figure 24 shows the pass-by noise at constant speeds for three bus technologies. The 17 dBA difference between the electric trolleybus (green curve) and the diesel bus (blue curve) at the speed of 20 mph (= 32.2 km/h) is really striking. Given that dBA is counted on a logarithmic scale, this difference indicates that an e-bus is about half as noisy as its diesel counterpart is. Of course, at higher speeds the noise differential drops as the main source of noise is the tyres rather than the engine. However, the dense traffic conditions in Kathmandu slow down vehicle movement. At an average speed of 17 to 25 km/h (GGGI, 2018b), the shift to e-mobility is expected to have a significant effect on noise.

8 The entire generation of electricity in Nepal takes place in hydropower plants (NEA, 2022). This does not apply to a share of less than 10% of total available electricity in FY 2021/22 that was imported from India. However, imports are expected to be replaced soon by locally produced electricity when new hydropower stations come online.

9 In the context of the present study, the PM emissions are restricted to exhaust sources. PM emissions from non-exhaust sources include those generated by the wearing down of brakes, clutches, tyres and road surfaces, as well as by the suspension of road dust. Although lightweight EVs emit an estimated 11-13% less non-exhaust PM2.5 than ICEV equivalents, heavier weight EVs emit an estimated 3-8% more PM2.5 than ICEVs (OECD, 2020).

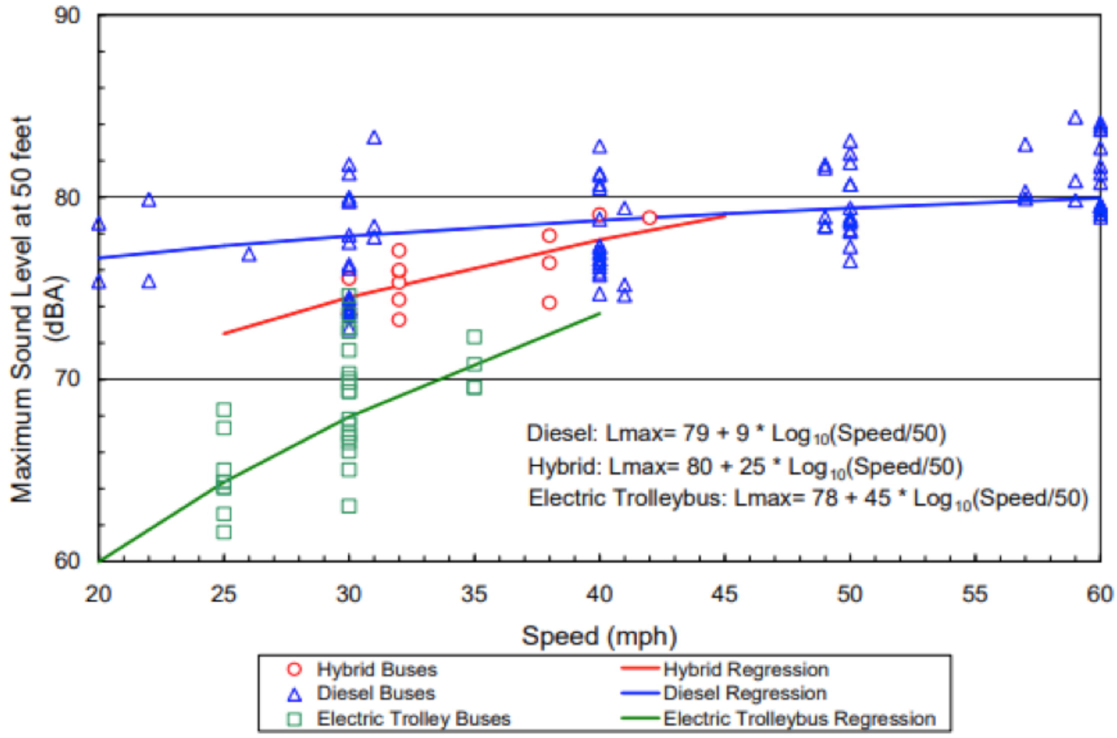


Figure 24. Speed-noise diagrams for various bus technologies (Source: Ross & Staiano, 2007)

Changes in average noise levels [in dB(A)]											
Vehicle (route)	Obs.	Date	Time		Measurements					Mean	**Score**
			Start	End	MIN	LA90	LA50	LA10	MAX	LA50	
Diesel bus (Lagenkhel-Ratnapark)	# 1	01-03-2023	14:09	14:39	65,1	73,4	78,0	83,3	91,8	80,80	
	# 2	01-03-2023	17:38	18:07	71,5	77,4	83,6	89,0	92,8		
Converted bus (within Sajha depot)	# 1	10-06-2024	11:00	11:02	56,1	57,0	58,3	61,7	69,5	57,55	
	# 2	10-06-2024	11:03	11:06	54,0	55,0	56,8	74,9	75,3		
					Difference in mean LA50					**-23,25**	**5**
Perceived noise exposure (2 drivers)											
1 The NEW solution is significantly noisier than the OLD one										0	
2 The NEW solution is slightly noisier than the OLD one										0	
3 There is no difference between the two solutions in relation to noise										0	
4 The OLD solution is slightly noisier than the NEW one										0	
5 The OLD solution is significantly noisier than the NEW one										2	**5**
										OVERALL SCORE	**5**

Table 12. Noise performance of the converted bus

These estimates are confirmed by the actual noise measurements shown in Table 12. Two NoiseCapture measurements were taken inside each one of the two vehicles assessed, a diesel bus along the Lagenkhel-Ratnapark route on 01/03/2023 and the converted bus within the Sajha Yatayat depot on 10/06/2024 (the vehicle could not leave the depot as the license had not been issued at the time of measurement). It appears that the converted bus reduces the noise generated by its diesel counterpart by 23.25 dB(A) in terms of LA50 on average. Although the ambient noise is certainly an issue, the difference is sufficiently high for a partial score of 5 according to the definition of the noise indicator (Vol. 1, Appendix B, Section B4.2). Both interviewed drivers of the converted bus agree that the diesel bus is significantly noisier than the converted one, which is also partially scored with a 5. Thus, the overall score of this vehicle in terms of noise is 5.

3.4.3. EFFECT ON SERVICE QUALITY

Unfortunately, the lack of license did not allow soliciting passenger views on service quality. As such, the relevant indicators were valued on the responses of just two drivers, shown in Table 13.

Score	Description	Respondents		Overall
		Number	Share	score
E.13	**Perceived comfort**			
1	OLD solution much more comfortable than NEW one		0,00%	
2	OLD solution more comfortable than NEW one		0,00%	
3	No difference between the two solutions		0,00%	
4	NEW solution more comfortable than OLD one	2	100,00%	
5	NEW solution much more comfortable than OLD one		0,00%	
	Total	**2**	**100,00%**	**4,00**
E.14	**Perceived drivability (professional drivers)**			
1	OLD solution much easier to drive than NEW one		0,00%	
2	OLD solution easier to drive than NEW one		0,00%	
3	No difference between the two solutions		0,00%	
4	NEW solution easier to drive than OLD one	2	100,00%	
5	NEW solution much easier to drive than OLD one		0,00%	
	Total	**2**	**100,00%**	**4,00**
E.16	**Perceived chargeability (professional drivers)**			
1	OLD solution much easier to charge/refuel than NEW one		0,00%	
2	OLD solution easier to charge/refuel than NEW one	2	100,00%	
3	No difference between the two solutions		0,00%	
4	NEW solution easier to charge/refuel than OLD one		0,00%	
5	NEW solution much easier to charge/refuel than OLD one		0,00%	
	Total	**2**	**100,00%**	**2,00**
E.17	**Perceived safety**			
1	OLD solution much safer than NEW one		0,00%	
2	OLD solution safer than NEW one		0,00%	
3	No difference between the two solutions		0,00%	
4	NEW solution safer than OLD one	1	50,00%	
5	NEW solution much safter than OLD one	1	50,00%	
	Total	**2**	**100,00%**	**4,50**

Table 13. Service quality indicators for the converted bus

3.5. REMODELLED SAFA TEMPO – PASSENGER SERVICE

3.5.1. FINANCIAL VIABILITY

During 1993-2011, a total of 721 electric 3-wheelers (Safa Tempos) were locally assembled in Kathmandu with the support of the Global Resources Institute (GRI) and the United States Agency of International Development (USAID). In 2011, the government decided to restrict new registrations of this type of vehicles due to congestion on the smaller tertiary routes that Safa Tempos tend to ply (GGGI, 2018b). Since then, the number of registrations has remained unchanged, but the operational fleet is steadily dropping, currently estimated at about 700 units (Gautam, 2020). As they use lead acid batteries that require frequent charging in addition to being generally in poor condition, their remodelling is worth pursuing.

The remodelling activity of this component includes the replacement of the old lead acid battery set with a 23 kWh Li-ion battery, which will be sufficient for driving 117 km daily with one overnight charging. It also includes replacing motors and other components on the same chassis, new body works and upgrading the passenger cabin to make riding more comfortable.

Investor's perspective

The financial viability of an investment in a remodelled Safa Tempo is assessed here. The investor has no connection to the old vehicle, which is bought and remodelled by the manufacturer before being sold. The remodelled vehicle was originally built in 1999, meaning that its license will be valid until 2029. Assuming that the remodelling was completed by the end of 2022, this leaves a useful life of 7 years. However, given that the battery, the most expensive component of the vehicle, has a life expectancy of 2,000 cycles, it was decided to restrict the asset's useful life to 6 years, after which, the initial investment of 1.95 million NPR (about €13,760) will only be worth 231,000 NPR.

The vehicle will be deployed on the Lalitpur route with a round trip length of 13 km and will perform 9 trips (=117 km) daily for 330 days per year. On average, it will serve 250 passengers per day, earning 1.65 million NPR annually at an average fare of 20 NPR. The operating cost is analysed in Table 14 together with all other input values. The energy consumption is 0.167 kWh/km in the beginning of the battery's life, gradually increasing to 0.213 kWh/km by Year 6 (due to efficiency losses of the battery). A declining balance depreciation of 10% per year applies, as well as a flat income tax rate of 25%. Alternatively, there is a provision for a flat annual tax of 7,500 NPR.

The calculations are shown in Table 15. The resulting NPV (3.36 million NPR), IRR (57.8%) and a payback period of only 1.6 years indicate a very profitable investment before taxes. Although the 25% tax rate has a significant effect on the results, the profitability of the project remains solid. As expected, the effect of the flat tax scheme is minimal.

The robustness of this investment is confirmed by the sensitivity analysis of Figure 25. Even if the investment requirements are increased from 1.95 to 3.00 million NPR, the pre-tax NPV (at 10% discount rate) remains above 2 million NPR. Similarly, the expected revenues have to drop by more than 45% before the profitability of the project is reversed.

Remodelled safa tempo - Passenger service - Investor's perspective - Input values				
Category	**Parameter**	**Value**	**Units**	**Comments**
General info	Year built	1999		
	Year remodelled	2022		
	Passenger capacity	11		
Propulsion	Battery type	Li-ion		
	Battery size	23	kWh	Only 20 kWh can be used before recharging
	Number of batteries	1		
Capital cost	Purchase price	1.950.000	NPR	=13.760 € (at 141,7226 NPR/€ on 31 Dec. 2022)
	Expected useful life	6	years	Administratively, the license lasts for 7 years (until 2029). However, the battery which is the most expensive part of the vehicle has a life expectancy of 2000 cycles, which is about 6 years.
	Residual value	231.000	NPR	= 40.000 (body) + 30.000 (drive train) + 161.000 (battery: 7.000 NPR/kWh)
	Depreciation schedule	10%		Per year (Declining balance method)
Operational profile	Route	Lalitpur		
	Length of round trip	13	km	
	Round trips/day	9	trips/day	
	Total distance/day	117	km/day	(=C15*C14)
	Operating days/year	330	days/year	
	Passengers/day	250	pax	
	Chargings/day	1		Overnight charging (plus some opportunity charging to cover battery efficiency drop)
Yearly operating cost	Total operating cost	438.058	NPR/year	(=sum(C21:C26)+C30+C34+C36)
	* Licencing/renewal	500	NPR/year	
	* Route permit	2.000	NPR/year	
	* Vehicle road tax	3.000	NPR/year	
	* Technical inspection	1.600	NPR/year	
	* Insurance	12.000	NPR/year	
	* Personnel cost	261.300	NPR/year	(=(C27+C28)*12+C29)
	- Basic monthly salary	18.000	NPR/month	
	- Monthly allowance	3.000	NPR/month	
	- Yearly bonus	9.300	NPR/year	
	* Electricity cost	45.045	NPR/year	(=C32*C16*C17*C33)
	- Battery efficiency	100,00	%	Annual drop of 4%
	- Specific energy consumption	0,167	kWh/km	Assuming that 20 kWh are needed for 120 km.
	- Electricity tariff	7	NPR/kWh	Special tariff for public transport EVs
	* Maintenance & parking cost	112.613	NPR/year	(=C32*C16*C17*C35)
	- Cost per kWh	17,5	NPR/kWh	(Includes maintenance and parking at the depo)
	* Other	0	NPR/year	
Yearly revenues	Total revenues	1.650.000	NPR/year	(=C17*C18*C38)
	Ticket fare/passenger	20	NPR	
Income tax	Income tax rate	25%		Alternatively, 7.500 NPR flat.

Table 14. Input values for assessing 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						

Table 15. Financial indicators for the remodeled Safa Tempo (Investor’s perspective)

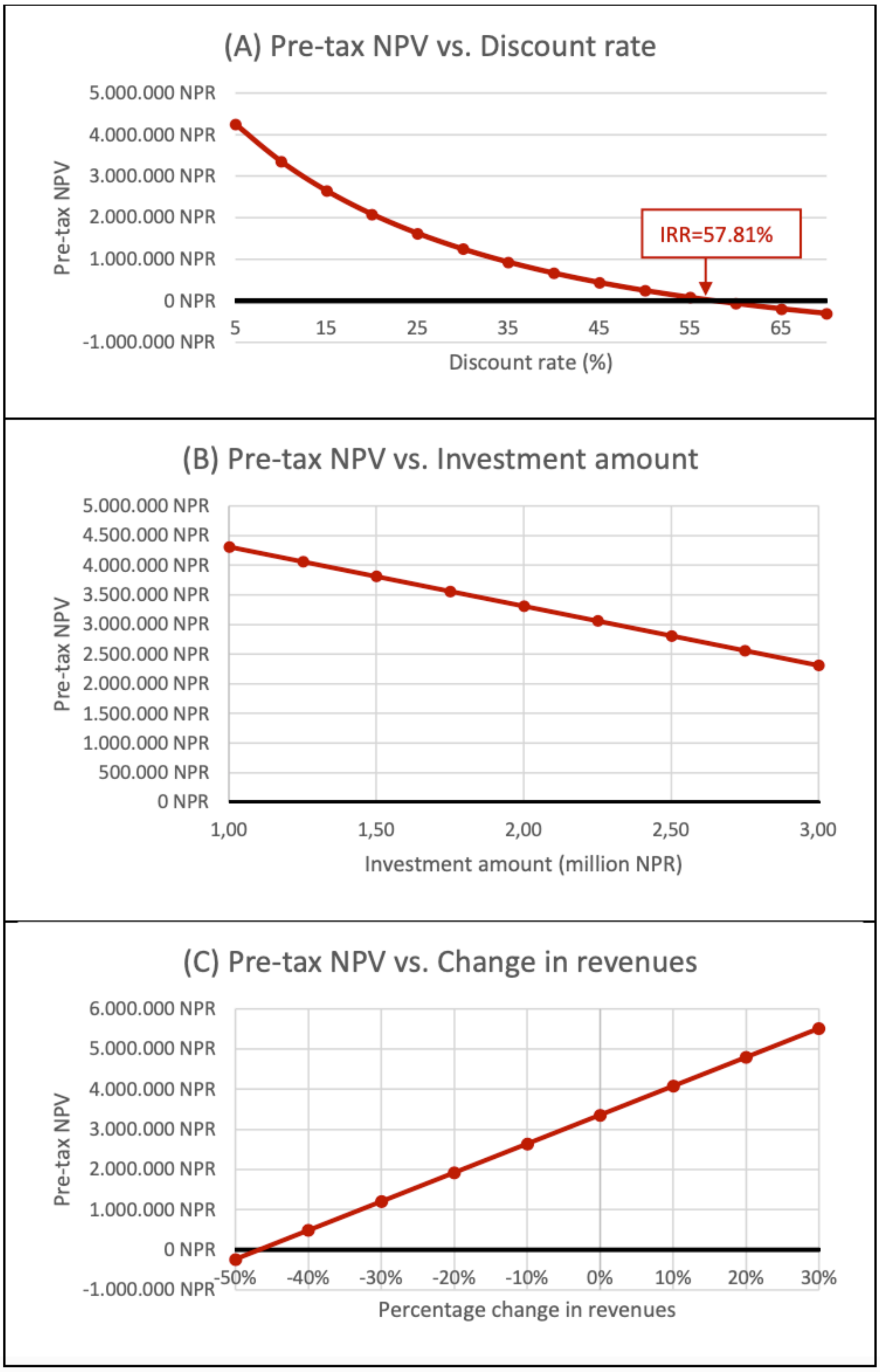


Figure 25. Remodelled Safa Tempo – passengers: Sensitivity analysis on pre-tax NPV

Operator's perspective

The investor's perspective investigated above silently assumes that the manufacturer will possess an existing Safa Tempo to remodel. If this vehicle happens to be laid up, there is no problem with this assumption other than seriously limiting the applicability of this intervention to just the non-operational Safa Tempos of the valley. If, on the other hand, one wants to extent applicability to all existing units, a different scenario needs to be assessed. Is the remodelling financially meaningful for the owner of an operational unit? To address this question, one needs to estimate the expected profitability of the current operation and reassess the remodelling option while considering the foregone profits as an additional cost.

At a current (2022) value of about 1.2 million NPR, the existing vehicle will continue running for 7 years when its license expires. It is equipped with two batteries of 14.4 kWh (each consisting of 12 identical elements), which need to be swapped during the day. These batteries need to be replaced every year at a net cost of 594,000 NPR after subtracting the resale value of the old ones. Due to the lower energy generated by these batteries at the beginning and the end of their life, an average utilisation rate of 0.906 is estimated for this vehicle, affecting proportionally the average number of daily passengers and the annual revenues (refer to Table 16 for the input values).

Remodelled Safa Tempo - Passenger service - BEFORE remodelling - Input values				
Category	**Parameter**	**Value**	**Units**	**Comments**
General info	Year built	1999		
	Year remodelled	2022		
	Passenger capacity	11		
Propulsion	Battery type	Lead acid		
	Battery size	14,4	kWh	Only 80% (=11,5 kWh) can be used before recharging [per unit]
	Number of batteries	2		
Capital cost	Market value	1.215.000	NPR	(=C10+C11)
	* Body	540.000	NPR	(=4.000 EUR*135 NPR/EUR (Nov 22))
	* New battery set	675.000	NPR	(=5.000 EUR*135 NPR/EUR (Nov 22))
	Expected useful life	7	years	As of today, there is a 30 year license for this vehicle (1999-2029)
	Residual value	96.000	NPR	(=15.000 for body + 81.000 for old battery set [=2 sets*12 elements*25 USD *135 NPR/USD])
	Depreciation schedule	10%		Per year (declining balance method)
Operational profile	Route	Lalitpur		
	Length of round trip	13	km	
	Round trips/day	9	trips/day	
	Total distance/day	117	km/day	(=C17*C16)
	Operating days/year	330	days/year	
	Passengers/day -Max	250	pax	Applies when vehicle can operate @ 100% of utilisation (9 trips/day)
	Utilisation rate due to battery performance	0,906		4,5 months @ 75% utilisation plus 7,5 months @ 100%
	Passengers/day -Avg	226,56	pax	Due to reduced km per charging
	Chargings/day	1		Overnight charging
Yearly operating cost	Total operating cost	1.055.706	NPR/year	(=sum(C25:C30)+C34+C37+C39)
	* Licencing/renewal	500	NPR/year	
	* Route permit	2.000	NPR/year	
	* Vehicle road tax	3.000	NPR/year	
	* Technical inspection	1.600	NPR/year	
	* Insurance	12.000	NPR/year	
	* Personnel cost	261.300	NPR/year	(=(C31+C32)*12+C33)
	- Basic monthly salary	18.000	NPR/month	
	- Monthly allowance	3.000	NPR/month	
	- Yearly bonus	9.300	NPR/year	
	* Electricity cost	51.802	NPR/year	(=C35*C18*C19*C36)
	- Energy consumption	0,192	kWh/km	Assuming 23 (=2*11,5) kWh are needed for 120 km
	- Electricity tariff	7	NPR/kWh	Special tariff for public transport EVs
	* Maintenance & parking	129.504	NPR/year	(=C38*C18*C19*C35)
	- Cost per kWh	17,5	NPR/kWh	(includes both maintenance and parking cost at the depot)
	* Other (battery replacement)	594.000	NPR/year	(=675.000-81.000) [New lead acid battery minus resale value of old battery set; battery set needs replacement every year]
Yearly revenues	Total revenues	1.495.313	NPR/year	(=C19*C22*C41)
	Ticket fare/passenger	20	NPR	
Income tax	Income tax rate	25%		Alternatively, 7.500 NPR per year flat.

Table 16. Input values for assessing existing operation (Operator's perspective)

The results of Table 17 show a positive NPV (for a discount rate of 10%) ranging from 0.58 to 1.28 million NPR depending on how tax is treated. If then, the capital cost of the investor's analysis (Table 14), after subtracting the market value of the vehicle body that the manufacturer will not have to acquire anymore, is inflated by the foregone profits of Table 17, and all other parameters of Table 14 remain as are, the profitability of the remodelling project is altered as shown in Table 18. The comparison with Table 17 reveals that all financial indicators improve significantly, indicating a clear financial incentive to undertake the remodelling project, despite the profitability of current operations.

Remodelled Safa Tempo - Passenger service - BEFORE remodelling - Calculations								
Discount rate	10%							
	Y0	Y1	Y2	Y3	Y4	Y5	Y6	Y7
Year	2022	2023	2024	2025	2026	2027	2028	2029
Investment	-1.215.000							
Residual value								96.000
Annual revenues		1.495.313	1.495.313	1.495.313	1.495.313	1.495.313	1.495.313	1.495.313
Annual operating & maintenance costs		-1.055.706	-1.055.706	-1.055.706	-1.055.706	-1.055.706	-1.055.706	-461.706
Net pre-tax cash flow	-1.215.000	439.606	439.606	439.606	439.606	439.606	439.606	1.129.606
Cumulative pre-tax cash flow	-1.215.000	-775.394	-335.787	103.819	543.426	983.032	1.422.638	2.552.245
Year	0	1	2	3	4	5	6	7
Pre-tax NPV	1.279.267							
Pre-tax IRR	34,01%							
Pre-tax payback (years)	2,76							
INCOME TAX RATE OF 25%								
Depreciation		0	0	0	0	0	0	0
Revenues from 2nd hand battery sale		81.000	81.000	81.000	81.000	81.000	81.000	81.000
Taxable income		520.606	520.606	520.606	520.606	520.606	520.606	1.048.606
Income tax		-130.152	-130.152	-130.152	-130.152	-130.152	-130.152	-262.152
Net after-tax cash flow	-1.215.000	309.455	309.455	309.455	309.455	309.455	309.455	867.455
Cumulative after-tax cash flow	-1.215.000	-905.545	-596.090	-286.636	22.819	332.274	641.729	1.509.183
Year	0	1	2	3	4	5	6	7
After-tax NPV	577.898							
After-tax IRR	21,47%							
After-tax payback (years)	3,93							
ALTERNATIVELY: FLAT INCOME TAX OF 7.500 NPR								
Income tax		-7.500	-7.500	-7.500	-7.500	-7.500	-7.500	-7.500
Net after-tax cash flow	-1.215.000	432.106	432.106	432.106	432.106	432.106	432.106	1.122.106
Cumulative after-tax cash flow	-1.215.000	-782.894	-350.787	81.319	513.426	945.532	1.377.638	2.499.745
Year	0	1	2	3	4	5	6	7
After-tax NPV	1.242.754							
After-tax IRR	33,35%							
After-tax payback (years)	2,81							

Table 17. Profitability of existing operation (Operator's perspective)

3.5.2. EFFECT ON EMISSIONS AND OTHER ENVIRONMENTAL ATTRIBUTES

Since in this case, the remodelled vehicle will replace another electric vehicle, there are no effects expected on any of the emissions examined here. Nor should there be an effect on the noise generated by its operation. However, among the 85 passengers who responded to the relevant question of the service quality survey (refer to Section 3.5.3), 48 (or 56.5%) found the old vehicle to be noisier than the remodelled one, and 17 (20.0%) found it much noisier. The average score was 3.86 in a scale from 1 (worst score) to 5 (best score). It is assumed that this perception is unrelated to the drive train of the vehicle.

Remodelled Safa Tempo - Passenger service - AFTER remodelling - Calculations							
Discount rate	10%						
	Y0	Y1	Y2	Y3	Y4	Y5	Y6
Year	2022	2023	2024	2025	2026	2027	2028
Investment	-2.608.267						
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	-2.608.267	1.205.373	1.198.531	1.191.403	1.183.978	1.176.244	1.399.187
Cumulative pre-tax cash flow	-2.608.267	-1.402.894	-204.363	987.040	2.171.018	3.347.261	4.746.448
Year	0	1	2	3	4	5	6
Pre-tax NPV	2.701.999						
Pre-tax IRR	40,23%						
Pre-tax payback (years)	2,17						
INCOME TAX RATE OF 25%							
Depreciation		-117.900	-106.110	-95.499	-85.949	-77.354	-69.619
Book value		1.061.100	954.990	859.491	773.542	696.188	626.569
Taxable income		1.087.473	1.092.421	1.095.904	1.098.029	1.098.889	702.999
Income tax		-271.868	-273.105	-273.976	-274.507	-274.722	-175.750
Net after-tax cash flow	-1.906.898	933.505	925.425	917.427	909.471	901.521	1.223.437
Cumulative after-tax cash flow	-1.906.898	-973.393	-47.967	869.460	1.778.930	2.680.452	3.903.889
Year	0	1	2	3	4	5	6
After-tax NPV	2.267.387						
After-tax IRR	43,68%						
After-tax payback (years)	2,05						
ALTERNATIVELY: FLAT INCOME TAX OF 7.500 NPR PER YEAR							
Income tax		-7.500	-7.500	-7.500	-7.500	-7.500	-7.500
Net after-tax cash flow	-2.571.754	1.197.873	1.191.031	1.183.903	1.176.478	1.168.744	1.391.687
Cumulative after-tax cash flow	-2.571.754	-1.373.880	-182.850	1.001.053	2.177.531	3.346.274	4.737.962
Year	0	1	2	3	4	5	6
After-tax NPV	2.705.848						
After-tax IRR	40,65%						
After-tax payback (years)	2,15						

Table 18. Profitability of the remodelling project (Operator's perspective)

3.5.3. EFFECT ON SERVICE QUALITY

The relevant indicators on service quality (refer to Table 19) are based on survey responses obtained from passengers of the remodelled vehicle during the period 30 April to 8 May 2023. A total number of 87 responses were collected, although not all of them are complete. This does not apply to the KPIs on perceived drivability and chargeability, which were estimated based on interviews with the two drivers of the remodelled Safa Tempo. An overall score of higher than 3 on all these KPIs indicates that the users/drivers perceive the remodelled vehicle as outperforming the old one. Particularly for the rather sensitive issue of personal security, it seems that the more concerned groups of passengers give lower marks to this indicator, although still above 3. Against a total score of 3.53, travellers with mobility problems assess it at 3.33, female passengers with 3.32, passengers of age <20 with 3.39, and passengers of age 60-79 with 3.00.

In relation to the suitability of the remodelled vehicle for travellers with mobility problems, which does not appear in the KPI structure as it was proposed at a later stage by the Project Officer, it appears that the vehicle performs below average with a score of 3.24 in a 7-point scale. It is worth noting that for this attribute, the 87 passengers assessed the vehicle on its own merits without comparing it to the old Safa Tempo. Interestingly, the 12 passengers among them who reported mobility problems marked it at 5.08.

Score	Description	Respondents		Overall
		Number	Share	score
E.12	**Suitability for adverse weather conditions**			
1	OLD solution much better than NEW one	2	2,30%	
2	OLD solution better than NEW one	1	1,15%	
3	No difference between the two solutions	33	37,93%	
4	NEW solution better than OLD one	37	42,53%	
5	NEW solution much better than OLD one	14	16,09%	
	Total	**87**	**100,00%**	**3,69**
E.13	**Perceived comfort**			
1	OLD solution much more comfortable than NEW one	0	0,00%	
2	OLD solution more comfortable than NEW one	0	0,00%	
3	No difference between the two solutions	12	13,79%	
4	NEW solution more comfortable than OLD one	55	63,22%	
5	NEW solution much more comfortable than OLD one	20	22,99%	
	Total	**87**	**100,00%**	**4,09**
E.14	**Perceived drivability (professional drivers)**			
1	OLD solution much easier to drive than NEW one	0	0,00%	
2	OLD solution easier to drive than NEW one	0	0,00%	
3	No difference between the two solutions	0	0,00%	
4	NEW solution easier to drive than OLD one	1	50,00%	
5	NEW solution much easier to drive than OLD one	1	50,00%	
	Total	**2**	**100,00%**	**4,50**
E.16	**Perceived chargeability (professional drivers)**			
1	OLD solution much easier to charge/refuel than NEW one	0	0,00%	
2	OLD solution easier to charge/refuel than NEW one	0	0,00%	
3	No difference between the two solutions	0	0,00%	
4	NEW solution easier to charge/refuel than OLD one	1	50,00%	
5	NEW solution much easier to charge/refuel than OLD one	1	50,00%	
	Total	**2**	**100,00%**	**4,50**
E.17	**Perceived safety**			
1	OLD solution much safer than NEW one	1	1,15%	
2	OLD solution safer than NEW one	0	0,00%	
3	No difference between the two solutions	32	36,78%	
4	NEW solution safer than OLD one	45	51,72%	
5	NEW solution much safter than OLD one	9	10,34%	
	Total	**87**	**100,00%**	**3,70**
E.18	**Perceived personal security**			
1	OLD solution much more secure than NEW one	0	0,00%	
2	OLD solution more secure than NEW one	2	2,33%	
3	No difference between the two solutions	47	54,65%	
4	NEW solution more secure than OLD one	26	30,23%	
5	NEW solution much more secure than OLD one	11	12,79%	
	Total	**86**	**100,00%**	**3,53**

Table 19. Service quality indicators for the remodelled Safa Tempo - passengers

3.6. REMODELLED SAFA TEMPO – CARGO SERVICE

3.6.1. FINANCIAL VIABILITY

A Safa Tempo, identical to the one of Section 3.5, is now remodelled into a cargo vehicle. In addition to replacing the old lead acid battery set with a 23 kWh Li-ion battery, the passenger cabin of the old vehicle will be replaced by a cargo bed able of carrying up to 1,000 kg (although the license is restricted to a maximum freight load of 500 kg).

Investor's perspective

As in Section 3.5.1, this assessment concerns the scenario of an investor directly buying the remodelled vehicle from the manufacturer. Once again, the expected battery life restricts the useful life of the vehicle to 6 years, after which, the initial investment of 1.95 million NPR (about €13,760) will only be worth 231,000 NPR.

Remodelled Safa Tempo - Cargo service - Investor's perspective - Input values				
Category	**Parameter**	**Value**	**Units**	**Comments**
General info	Year built	1999		
	Year remodelled	2022		
	Payload capacity	1.000	Kg	Formally only 500 kg (according to bluebook)
Propulsion	Battery type	Li-ion		
	Battery size	23	kWh	Only 20 kWh can be used before recharging
	Number of batteries	1		
Capital cost	Purchase price	1.950.000	NPR	
	Expected useful life	6	years	Based on the charging cycles of the battery (2.000 cycles)
	Residual value	231.000	NPR	= 40.000 (body) + 30.000 (drive train) + 161.000 (battery: 7.000 NPR/kWh)
	Depreciation schedule	10%		Per year (Declining balance method)
Operating profile	Average length of trip	20	km	
	Paid trips/day	3,5	trips/day	
	Total distance/day	70	km/day	(=C14*C13)
	Operating days/year	330	days/year	
Yearly operating cost	Total operating cost	511.400	NPR/year	(=sum(C18:C22)+C26+C30+C42)
	* Licencing/renewal	0	NPR/year	
	* Vehicle road tax	3.000	NPR/year	
	* Technical inspection	0	NPR/year	
	* Insurance	12.000	NPR/year	
	* Personnel cost	380.000	NPR/year	(=(C23+C24)*12+C25)
	- Basic monthly salary	20.000	NPR/month	
	- Monthly allowance	10.000	NPR/month	
	- Yearly bonus	20.000	NPR/year	
	* Electricity cost	26.950	NPR/year	(=C15*C16*C28*C29)
	- Battery efficiency	100,00	%	Annual drop of 4% on average
	- Specific energy consumption	0,167	kWh/km	Assuming that 20 kWh are needed for 120 km.
	- Electricity tariff	7	NPR/kWh	Special tariff for public transport EVs
	* Maintenance cost	56.550	NPR/year	(=sum(C31:C41))
	- Tires	13.000	NPR/year	(26.000 NPR every 2 years)
	- Break shoes	4.000	NPR/year	
	- Dent paint	20.000	NPR/year	(60.000 NPR every 3 years)
	- Suspension	3.000	NPR/year	
	- Wiring	4.500	NPR/year	
	- Headlights, tail lights	3.500	NPR/year	
	- Fuses	1.550	NPR/year	
	- Display system	2.000	NPR/year	
	- Throttle pedal	5.000	NPR/year	
	- Battery change	0	NPR/year	
	- Motor service	0	NPR/kWh	
	* Other	32.900	NPR/year	(=sum(C43:C46))
	- Parking	18.000	NPR/year	(1.500 NPR per month)
	- Vehicle cleaning	14.400	NPR/year	(4 times per month at 300 NPR each time)
	- Driver license	500	NPR/year	
	- Other	0	NPR/year	
Yearly revenues	Total revenues	1.732.500	NPR/year	(=C16*C14*C48)
	Charge per trip	1.500	NPR	
Income tax	Income tax rate	25%		Alternatively, 7.500 NPR flat.

Table 20. Input values for assessing the remodelled cargo e3W (Investor's perspective)

The vehicle is expected to perform on average 3.5 paid trips per day of about 20 km each. Based on market information, average earnings of 1.500 NPR are assumed per trip, which results in 1.732.500 NPR per year (at 330 working days annually). Table 20 summarises the input values for the assessment, the results of which are presented in Table 21. With an NPV of 3.48 million NPR (at 10% discount rate), an IRR of 59.06% and a payback period of 1.6 years, the profitability of this remodelling is similar to that of its passenger counterpart. The results are equally robust, too. The sensitivity analysis results in values so close to those of Figure 25 that their reproduction here makes no sense as the differences are invisible.

Remodelled Safa Tempo - Cargo 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		1.732.500	1.732.500	1.732.500	1.732.500	1.732.500	1.732.500
Annual operating & maintenance costs		-512.523	-513.693	-514.911	-516.180	-517.502	-518.880
Net pre-tax cash flow	-1.950.000	1.219.977	1.218.807	1.217.589	1.216.320	1.214.998	1.444.620
Cumulative pre-tax cash flow	-1.950.000	-730.023	488.784	1.706.373	2.922.693	4.137.691	5.582.311
Year	0	1	2	3	4	5	6
Pre-tax NPV	3.481.773						
Pre-tax IRR	59,06%						
Pre-tax payback (years)	1,60						
		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		1.048.077	1.064.097	1.078.350	1.091.005	1.102.214	198.568
Income tax		-262.019	-266.024	-269.587	-272.751	-275.554	-49.642
Net after-tax cash flow	-1.950.000	957.958	952.783	948.001	943.569	939.444	1.394.978
Cumulative after-tax cash flow	-1.950.000	-992.042	-39.259	908.742	1.852.311	2.791.755	4.186.733
Year	0	1	2	3	4	5	6
After-tax NPV	2.435.762						
After-tax IRR	44,56%						
After-tax payback (years)	2,04						
		ALTERNATIVELY: FLAT INCOME TAX OF 7,500 NPR					
Income tax		-7.500	-7.500	-7.500	-7.500	-7.500	-7.500
Net after-tax cash flow	-1.950.000	1.212.477	1.211.307	1.210.089	1.208.820	1.207.498	1.437.120
Cumulative after-tax cash flow	-1.950.000	-737.523	473.784	1.683.873	2.892.693	4.100.191	5.537.311
Year	0	1	2	3	4	5	6
After-tax NPV	3.449.108						
After-tax IRR	58,64%						
After-tax payback (years)	1,61						

Table 21. Financial indicators for the remodelled cargo e3W (Investor's perspective)

Operator's perspective

Once again, there is the need to investigate whether the operators of the existing Safa Tempos have any incentive to proceed with this remodelling. Given that the original vehicle is a passenger e3W identical to that of Section 3.5.1, its expected profitability is no different than that of Table 17. The NPVs of Table 17, then, become an additional cost (foregone profit) for the remodelling investment, which however needs to be reduced by the market value of the vehicle body (540.000 NPR) and the residual value of the old battery set (81.000 NPR). The obtained results appear in Table 22. The comparison with Table 17 reveals that the remodelling exhibits improved profitability, indicating a clear incentive to undertake the remodelling project, despite the profitability of current operations.

Remodelled Safa Tempo - Cargo service - AFTER remodelling - Calculations							
Discount rate	10%						
	Y0	**Y1**	**Y2**	**Y3**	**Y4**	**Y5**	**Y6**
Year	2022	2023	2024	2025	2026	2027	2028
Investment	-2.608.267						
Residual value							231.000
Annual revenues		1.732.500	1.732.500	1.732.500	1.732.500	1.732.500	1.732.500
Annual operating & maintenance costs		-512.523	-513.693	-514.911	-516.180	-517.502	-518.880
Net pre-tax cash flow	-2.608.267	1.219.977	1.218.807	1.217.589	1.216.320	1.214.998	1.444.620
Cumulative pre-tax cash flow	-2.608.267	-1.388.290	-169.483	1.048.106	2.264.426	3.479.424	4.924.044
Year	0	1	2	3	4	5	6
Pre-tax NPV	2.823.506						
Pre-tax IRR	41,29%						
Pre-tax payback (years)	2,14						
INCOME TAX RATE OF 25%							
Depreciation		-117.900	-106.110	-95.499	-85.949	-77.354	-69.619
Book value		1.292.100	1.185.990	1.090.491	1.004.542	927.188	857.569
Taxable income		1.102.077	1.112.697	1.122.090	1.130.371	1.137.643	517.433
Income tax		-275.519	-278.174	-280.522	-282.593	-284.411	-129.358
Net after-tax cash flow	-1.906.898	944.458	940.633	937.066	933.727	930.587	1.315.262
Cumulative after-tax cash flow	-1.906.898	-962.440	-21.807	915.260	1.848.987	2.779.573	4.094.836
Year	0	1	2	3	4	5	
After-tax NPV	2.391.115						
After-tax IRR	44,92%						
After-tax payback (years)	2,02						
ALTERNATIVELY: FLAT INCOME TAX OF 7.500 NPR PER YEAR							
Income tax		-7.500	-7.500	-7.500	-7.500	-7.500	-7.500
Net after-tax cash flow	-2.571.754	1.212.477	1.211.307	1.210.089	1.208.820	1.207.498	1.437.120
Cumulative after-tax cash flow	-2.571.754	-1.359.277	-147.969	1.062.119	2.270.939	3.478.437	4.915.557
Year	0	1	2	3	4	5	6
After-tax NPV	2.827.354						
After-tax IRR	41,73%						
After-tax payback (years)	2,12						

Table 22. Profitability of the remodelling project – cargo (Operator's perspective)

3.6.2. Effect on emissions and other environmental attributes

Once remodelled into a cargo vehicle, the e3W will operate in a different market segment. To estimate the effect on emissions, a substitute vehicle in this segment must be identified. A 4-wheeler pick-up truck is a typical vehicle for urban freight in Kathmandu. The new petrol-driven pick-up truck of Table 29 (Section 3.8.1) has been selected for this purpose.

GHG emissions

Given that the deployment of the substitute pick-up truck will be identical to that of the remodelled Safa Tempo, and under the assumption that all electricity used by the e3W will be generated exclusively through renewable sources, the emissions of the pick-up truck reflect the emissions abated.

The average distance travelled by the pick-up truck is estimated at 70 km/day. Assuming an average deployment of 330 days per year (=27.5 days per month), its annual mileage amounts to 23,100 km. A field study undertaken by the city team in Kathmandu estimated that on average the specific fuel consumption of such a vehicle is 0.083 lt/km, leading to an annual consumption of 1,925 lt of petrol.

According to the e-Mob calculator of UNEP, petrol has a tank-to-wheel (TtW) and well-to-tank (WtT) CO2 emission factor of 2,500 gr/lt and 500 gr/lt respectively, resulting in a well-to-wheel (WtW) factor of 3,000 gr/lt.

The annual fuel consumption estimated above then results into 5.78 tonnes of CO2 emissions per year, which is the amount abated by one unit of the remodelled e3W.

NOx emissions

Based on Shrestha et al. (2013), the NOx emissions factor for petrol-driven pick-up trucks 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 26.49 kg of NOx emissions abated annually per unit of remodelled Safa Tempo.

PM2.5 emissions

Similarly, the PM2.5 emissions factor for this type of fuel and vehicle is 18,92 gr/lt (Das et al., 2022). The mass of abated PM2.5 emissions annually per unit of the remodelled cargo 3-wheeler then becomes 36,42 kg.

Noise

Two NoiseCapture measurements were taken inside each one of the two vehicles assessed along the Kalanki-Jawlakhel road segment on 06/04/2023 (refer to Table 23). It appears that the remodelled Safa Tempo reduces the noise generated by the pick-up truck by 4.7 dB(A) in terms of LA50 on average. According to the definition of the noise indicator (Vol. 1, Appendix B, Section B4.2), the partial score of this performance is 5. The driver of the remodelled Safa Tempo finds the pick-up truck significantly noisier than the e3W, which is also partially scored with a 5. Thus, the overall score of this vehicle in terms of noise is 5.

Changes in average noise levels [in dB(A)]										
Journey: Kalanki - Jawlakhel		Time		Measurements					Mean	**Score**
Date: 06/04/2023		Start	End	MIN	LA90	LA50	LA10	MAX	LA50	
Pick-up truck	# 1	16:23	16:32	73,4	78,5	82,7	87,6	94,8	81,85	
	# 2	16:33	16:38	75,1	77,4	81,0	83,3	91,8		
Remodelled Safa Tempo	# 1	13:27	13:35	62,5	69,5	75,0	80,2	95,1	77,15	
	# 2	13:38	13:45	70,1	75,3	79,3	85,8	97,2		
				Difference in mean LA50					**-4,7**	**5**
Perceived noise exposure (driver)										
1 The NEW solution is significantly noisier than the OLD one									0	
2 The NEW solution is slightly noisier than the OLD one									0	
3 There is no difference between the two solutions in relation to noise									0	
4 The OLD solution is slightly noisier than the NEW one									0	
5 The OLD solution is significantly noisier than the NEW one									1	**5**
									OVERALL SCORE	**5**

Table 23. Noise performance of the remodelled Safa Tempo - cargo

3.6.3. EFFECT ON SERVICE QUALITY

Unfortunately, during the demonstration period only one driver drove the remodelled Safa Tempo. As such, the indicators related to service quality were valued on just one response, which is shown in Table 24.

Score	Description	Respondents		Overall score
		Number	Share	
E.12	**Suitability for adverse weather conditions**			
1	OLD solution much better than NEW one		0,00%	
2	OLD solution better than NEW one		0,00%	
3	No difference between the two solutions	1	100,00%	
4	NEW solution better than OLD one		0,00%	
5	NEW solution much better than OLD one		0,00%	
	Total	**1**	**100,00%**	**3,00**
E.13	**Perceived comfort**			
1	OLD solution much more comfortable than NEW one		0,00%	
2	OLD solution more comfortable than NEW one	1	100,00%	
3	No difference between the two solutions		0,00%	
4	NEW solution more comfortable than OLD one		0,00%	
5	NEW solution much more comfortable than OLD one		0,00%	
	Total	**1**	**100,00%**	**2,00**
E.14	**Perceived drivability (professional drivers)**			
1	OLD solution much easier to drive than NEW one		0,00%	
2	OLD solution easier to drive than NEW one		0,00%	
3	No difference between the two solutions		0,00%	
4	NEW solution easier to drive than OLD one		0,00%	
5	NEW solution much easier to drive than OLD one	1	100,00%	
	Total	**1**	**100,00%**	**5,00**
E.16	**Perceived chargeability (professional drivers)**			
1	OLD solution much easier to charge/refuel than NEW one		0,00%	
2	OLD solution easier to charge/refuel than NEW one	1	100,00%	
3	No difference between the two solutions		0,00%	
4	NEW solution easier to charge/refuel than OLD one		0,00%	
5	NEW solution much easier to charge/refuel than OLD one		0,00%	
	Total	**1**	**100,00%**	**2,00**
E.17	**Perceived safety**			
1	OLD solution much safer than NEW one		0,00%	
2	OLD solution safer than NEW one	1	100,00%	
3	No difference between the two solutions		0,00%	
4	NEW solution safer than OLD one		0,00%	
5	NEW solution much safter than OLD one		0,00%	
	Total	**1**	**100,00%**	**2,00**
E.18	**Perceived personal security**			
1	OLD solution much more secure than NEW one		0,00%	
2	OLD solution more secure than NEW one		0,00%	
3	No difference between the two solutions	1	100,00%	
4	NEW solution more secure than OLD one		0,00%	
5	NEW solution much more secure than OLD one		0,00%	
	Total	**1**	**100,00%**	**3,00**

Table 24. Service quality indicators for the remodelled Safa Tempo - cargo

3.7. NEWLY DESIGNED E3WHEELER – PASSENGER SERVICE

3.7.1. FINANCIAL VIABILITY

In the early stages of SOLUTIONSplus, the possibility of developing a modular e3W that could be easily customised to a passenger, cargo, or waste collection operation [10]was considered worth pursuing. Due to the COVID pandemic at the time, a mini Safa Tempo (6-seater) option was selected as safer.

New 3-wheeler design - Passenger service - Input values				
Category	**Parameter**	**Value**	**Units**	**Comments**
General info	Year built	2023		
	Passenger capacity	6		
Propulsion	Battery type	LFP		
	Battery size	10	kWh	Only 80% (=8 kWh) can be used before recharging [per unit]
	Number of batteries	1		
Capital cost	Market value	1.150.000	NPR	(=sum(C9:C11))
	* Manufacturing	550.000	NPR	
	* Drive train	200.000	NPR	
	* Battery	400.000	NPR	
	Expected useful life	30	years	
	Residual value	145.000	NPR	(=C14+C15)
	* Body	75.000	NPR	After 30 years
	* Battery	70.000	NPR	After 6 years (7.000 NPR/kWh assuming healthy battery cells)
	Depreciation schedule	10%		Per year (declining balance method)
Operational profile	Route	Bhaktapur		
	Length of round trip	10	km	
	Round trips/day	10	trips/day	
	Total distance/day	100	km/day	(=C19*C18)
	Operating days/year	320	days/year	
	Passengers/day -Max	120	pax	
	Chargings/day	1		Overnight charging
Yearly operating cost	Total operating cost	388.540	NPR/year	(=sum(C25:C30)+C34+C38+C50)
	* Licencing/renewal	5.000	NPR/year	
	* Route permit	2.000	NPR/year	
	* Vehicle road tax	2.000	NPR/year	
	* Technical inspection	2.200	NPR/year	
	* Insurance	8.000	NPR/year	
	* Personnel cost	261.300	NPR/year	(=(C31+C32)*12+C33)
	- Basic monthly salary	18.000	NPR/month	
	- Monthly allowance	3.000	NPR/month	
	- Yearly bonus	9.300	NPR/year	
	* Electricity cost	17.920	NPR/year	(=C35*C20*C21*C37)
	- Energy consumption	0,080	kWh/km	Assuming 8 kWh are needed for 100 km
	- Battery efficiency	100,000	%	Annual drop of 4%
	- Electricity tariff	7	NPR/kWh	Special tariff for public transport EVs
	* Maintenance	37.300	NPR/year	(=sum(C39:C49))
	- Tires	6.000	NPR/year	Once per year (2.000 NPR per tire)
	- Brake shoes	6.000	NPR/year	
	- Dent paint	12.000	NPR/year	36.000 NPR every 3 years
	- Suspension	3.000	NPR/year	
	- Wiring	500	NPR/year	
	- Headlights, tail lights	1.500	NPR/year	
	- Independent axle	6.000	NPR/year	
	- Fuses	500	NPR/year	
	- Display system	1.000	NPR/year	
	- Thottle pedal	800	NPR/year	
	- Other	0	NPR/year	
	* Other	52.820	NPR/year	(=sum(C51:C53))
	- Vehicle cleaning	28.800	NPR/year	4 times per month at a cost of 600 NPR each time
	- Vehicle parking	24.000	NPR/year	2.000 NPR per month
	- Other	20	NPR/year	Stationary/ticketing
Yearly revenues	Total revenues	768.000	NPR/year	(=C21*C22*C55)
	Ticket fare/passenger	20	NPR	
Income tax	Income tax rate	25%		Alternatively, 7.500 NPR per year flat.

Table 25. Input values for assessing the newly designed passenger e3W

10 The waste collection option was later dropped due to poor financial performance and replaced by the conversion of a mini truck into an e-4 wheeler municipal waste collector vehicle (refer to Section 3.9).

The vehicle would be equipped with a lithium-iron-phosphate (LFP) 10 kWh battery, which at a purchase price of about 400,000 NPR could support operation for 6 years. A residual value of 70,000 NPR is estimated for this battery, assuming the battery cells remain healthy. The market value of the vehicle is expected to be 1.15 million NPR, dropping to 145,000 NPR after 30 years of operation (5 cycles of 6 years each based on the life duration of the battery).

New 3-wheeler design - Passenger service - Calculations

	Y0	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11	Y12
Discount rate	10%												
Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Investment	-1.150.000						-330.000						-330.000
Residual value													
Annual revenues		768.000	768.000	768.000	768.000	768.000	768.000	768.000	768.000	768.000	768.000	768.000	768.000
Annual operating & maintenance costs		-389.287	-390.064	-390.875	-391.719	-392.598	-393.513	-389.287	-390.064	-390.875	-391.719	-392.598	-393.513
Net pre-tax cash flow	-1.150.000	378.713	377.936	377.125	376.281	375.402	44.487	378.713	377.936	377.125	376.281	375.402	44.487
Cumulative pre-tax cash flow	-1.150.000	-771.287	-393.351	-16.226	360.056	735.458	779.945	1.158.658	1.536.593	1.913.719	2.290.000	2.665.403	2.709.889
Year	0	1	2	3	4	5	6	7	8	9	10	11	12
Pre-tax NPV	2.026.943												
Pre-tax IRR	30,58%												
Pre-tax payback (years)	3,04												
INCOME TAX RATE OF 25%													
Depreciation		-100.500	-90.450	-81.405	-73.265	-65.938	-59.344	-86.410	-77.769	-69.992	-62.993	-56.693	-51.024
Book value		1.049.500	959.050	877.645	804.381	738.442	679.098	922.688	844.920	774.928	711.935	655.241	604.217
Taxable income		278.213	287.486	295.720	303.017	309.464	315.142	292.304	300.167	307.133	313.289	318.709	323.462
Income tax		-69.553	-71.871	-73.930	-75.754	-77.366	-78.786	-73.076	-75.042	-76.783	-78.322	-79.677	-80.866
Net after-tax cash flow	-1.150.000	309.160	306.064	303.195	300.527	298.036	-34.299	305.637	302.894	300.342	297.959	295.725	-36.379
Cumulative after-tax cash flow	-1.150.000	-840.840	-534.776	-231.581	68.947	366.983	332.684	638.321	941.215	1.241.557	1.539.516	1.835.242	1.798.863
Year	0	1	2	3	4	5	6	7	8	9	10	11	12
After-tax NPV	1.315.147												
After-tax IRR	23,67%												
After-tax payback (years)	3,77												
ALTERNATIVELY: FLAT INCOME TAX OF 7.500 NPR													
Income tax		-7.500	-7.500	-7.500	-7.500	-7.500	-7.500	-7.500	-7.500	-7.500	-7.500	-7.500	-7.500
Net after-tax cash flow	-1.150.000	371.213	370.436	369.625	368.781	367.902	36.987	371.213	370.436	369.625	368.781	367.902	36.987
Cumulative after-tax cash flow	-1.150.000	-778.787	-408.351	-38.726	330.056	697.958	734.945	1.106.158	1.476.593	1.846.219	2.215.000	2.582.903	2.619.889
Year	0	1	2	3	4	5	6	7	8	9	10	11	12
After-tax NPV	1.956.242												
After-tax IRR	29,89%												
After-tax payback (years)	3,10												

	Y13	Y14	Y15	Y16	Y17	Y18	Y19	Y20	Y21	Y22	Y23	Y24	Y25	Y26	Y27	Y28	Y29	Y30
Year	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052
Investment						-330.000						-330.000						
Residual value																		145.000
Annual revenues	768.000	768.000	768.000	768.000	768.000	768.000	768.000	768.000	768.000	768.000	768.000	768.000	768.000	768.000	768.000	768.000	768.000	768.000
Annual operating & maintenance costs	-389.287	-390.064	-390.875	-391.719	-392.598	-393.513	-389.287	-390.064	-390.875	-391.719	-392.598	-393.513	-389.287	-390.064	-390.875	-391.719	-392.598	-393.513
Net pre-tax cash flow	378.713	377.936	377.125	376.281	375.402	44.487	378.713	377.936	377.125	376.281	375.402	44.487	378.713	377.936	377.125	376.281	375.402	519.487
Cumulative pre-tax cash flow	3.088.603	3.466.538	3.843.663	4.219.945	4.595.347	4.639.834	5.018.547	5.396.483	5.773.608	6.149.889	6.525.292	6.569.778	6.948.492	7.326.427	7.703.553	8.079.834	8.455.236	8.974.723
Year	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Depreciation	-78.922	-71.030	-63.927	-57.534	-51.781	-46.602	-74.942	-67.448	-60.703	-54.633	-49.170	-44.253	-72.827	-65.545	-58.990	-53.091	-47.782	-43.004
Book value	855.295	784.266	720.339	662.805	611.025	564.422	819.480	752.032	691.329	636.696	587.526	543.274	800.446	734.902	675.912	622.820	575.038	532.035
Taxable income	299.792	306.906	313.199	318.747	323.622	327.884	303.771	310.488	316.422	321.649	326.233	330.234	305.886	312.391	318.135	323.190	327.620	-55.552
Income tax	-74.948	-76.727	-78.300	-79.687	-80.905	-81.971	-75.943	-77.622	-79.106	-80.412	-81.558	-82.558	-76.471	-78.098	-79.534	-80.798	-81.905	13.888
Net after-tax cash flow	303.765	301.209	298.826	296.595	294.497	-37.484	302.771	300.314	298.020	295.869	293.844	-38.072	302.242	299.838	297.592	295.484	293.497	533.375
Cumulative after-tax cash flow	2.102.628	2.403.837	2.702.663	2.999.257	3.293.754	3.256.270	3.559.040	3.859.354	4.157.374	4.453.243	4.747.087	4.709.015	5.011.257	5.311.095	5.608.687	5.904.170	6.197.668	6.731.042
Year	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Income tax (flat)	-7.500	-7.500	-7.500	-7.500	-7.500	-7.500	-7.500	-7.500	-7.500	-7.500	-7.500	-7.500	-7.500	-7.500	-7.500	-7.500	-7.500	-7.500
Net after-tax cash flow (flat)	371.213	370.436	369.625	368.781	367.902	36.987	371.213	370.436	369.625	368.781	367.902	36.987	371.213	370.436	369.625	368.781	367.902	511.987
Cumulative after-tax cash flow (flat)	2.991.103	3.361.538	3.731.163	4.099.945	4.467.847	4.504.834	4.876.047	5.246.483	5.616.108	5.984.889	6.352.792	6.389.778	6.760.992	7.131.427	7.501.053	7.869.834	8.237.736	8.749.723
Year	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

Table 26. Financial indicators for the newly designed passenger e3W

The vehicle will be deployed on the Bhaktapur route with a round trip length of 10 km. It is expected to perform 10 round trips per day for 320 days per year. Assuming the same average vehicle utilisation with the Safa Tempo, an estimate of 120 passengers per day is derived after accounting for the difference in vehicle capacity and the distance travelled. Under this assumption, the expected annual revenues are estimated at 768,000 NPR. The input values for the financial assessment are presented in Table 25, while Table 26 calculates the financial indicators.

The project generates a healthy pre-tax NPV of 2.03 million NPR (at 10% discount rate), an IRR of 30.58%, and is paid back in a little over 3 years. The results are comparable to those of an existing Safa Tempo, which has an IRR of 34% and a payback period of 2.76 years but a lower NPV of 1.28 million NPR. An additional advantage over the Safa Tempo relates to the much longer useful life of the newly designed vehicle (assuming that it will obtain the necessary licence), which is of particular importance in the usual case of self-employed owners/drivers.

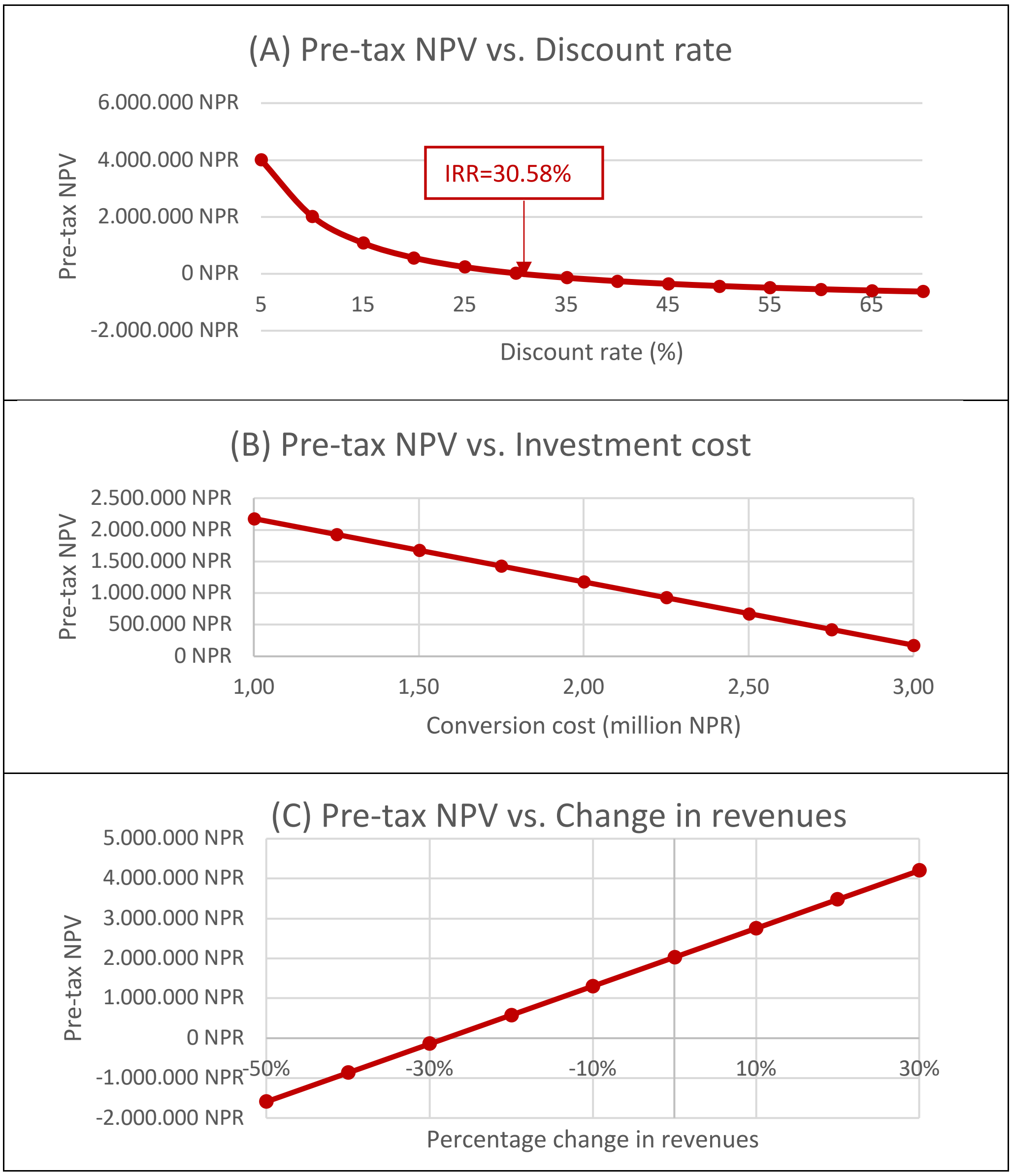


Figure 26. Newly designed e3W – passengers: Sensitivity analysis on pre-tax NPV

With regard to the sensitivity analysis of Figure 26, the investment appears robust in relation to the purchase price, which needs to treble before the NPV turns negative. However, it is more sensitive to expected revenues. A reduction of less than 28% in revenues is sufficient to nullify the NPV of the project.

3.7.2. EFFECT ON EMISSIONS AND OTHER ENVIRONMENTAL ATTRIBUTES

Since the newly designed vehicle is conceived as a replacement for another electric vehicle, there are no effects expected on any of the emissions examined here. Nor should there be an effect on the noise generated by its operation.

3.8. NEWLY DESIGNED E3WHEELER – CARGO SERVICE

3.8.1. FINANCIAL VIABILITY

The drive train and battery of this vehicle is identical to those of its passenger counterpart (Section 3.7.1). It is equipped with a cargo bed with a capacity of more than 500 kg, although its license is limited to that amount. It has an expected useful life of 18 years (3 cycles of 6 years based on the life expectancy of the battery). Its operational profile and expected earnings are identical to the remodelled Safa Tempo of Section 3.6.1. Table 27 summarises the input values for the assessment.

New cargo 3-wheeler - Investor's perspective - Input values				
Category	**Parameter**	**Value**	**Units**	**Comments**
General info	Year built	2022		
	Payload capacity	500	kg	
Propulsion	Battery type	LFP		(Lithion-iron-phosphate)
	Battery size	10	kWh	Only 80% (=8 kWh) can be used before recharging
	Number of batteries	1		
Capital cost	Purchase price	1.409.600	NPR	(=sum(C9:C11))
	- Manufacturing cost	809.600		
	- Cost of drive train	200.000		
	- Cost of battery	400.000		
	Expected useful life	18	years	Based on the life expectancy of the battery
	Residual value	140.000	NPR	(=C14+C15)
	- Body & drive train	70.000	NPR	After 18 years
	- Battery	70.000	NPR	After 6 years (7.000 NPR/kWh)
	Depreciation schedule	10%		Per year (Declining balance method)
Operating profile	Average length of trip	20	km	
	Paid trips/day	3,5	trips/day	
	Total distance/day	70	km/day	(=C18*C17)
	Operating days/year	330	days/year	
Yearly operating cost	Total operating cost	485.075	NPR/year	(=sum(C22:C24)+C28+C32+C44)
	* Vehicle road tax	0	NPR/year	
	* Insurance	8.000	NPR/year	
	* Personnel cost	373.000	NPR/year	(=(C25+C26)*12+C27)
	- Basic monthly salary	25.000	NPR/month	
	- Monthly allowance	4.000	NPR/month	
	- Yearly bonus	25.000	NPR/year	
	* Electricity cost	13.475	NPR/year	(=C19*C20*C30*C31)
	- Battery efficiency	100,00	%	Annual drop of 4%
	- Specific energy consumption	0,083	kWh/km	On the assumption that 90 km require 7,5 kWh
	- Electricity tariff	7	NPR/kWh	Special tariff for EVs
	* Maintenance cost	37.300	NPR/year	(=sum(C33:C43))
	- Tires	6.000	NPR/year	
	- Brake shoes	6.000	NPR/year	
	- Dent paint	12.000	NPR/year	
	- Suspension	3.000	NPR/year	
	- Wiring	500	NPR/year	
	- Headlights, tail lights	1.500	NPR/year	
	- Independent axle	6.000	NPR/year	
	- Fuses	500	NPR/year	
	- Display system	1.000	NPR/year	
	- Throttle pedal	800	NPR/year	
	- Other maintenance costs	0	NPR/year	
	* Other	53.300	NPR/year	(=sum(C45:C47))
	- Vehicle parking	24.000	NPR/year	(=2.000 NPR per month)
	- Vehicle cleaning	28.800	NPR/year	(=2.400 NPR per month)
	- Driver's license	500	NPR/year	
Yearly revenues	Total revenues	1.732.500	NPR/year	(=C20*C18*C49)
	Charge per trip	1.500	NPR/trip	
Income tax	Income tax rate	25%		Alternatively, 7.500 NPR flat.

Table 27. Input values for assessing the newly designed cargo e3W

Table 28. Financial indicators for the newly designed cargo e3W

New cargo 3-wheeler - Investor's perspective - Calculations																			
Discount rate	10%																		
	Y0	**Y1**	**Y2**	**Y3**	**Y4**	**Y5**	**Y6**	**Y7**	**Y8**	**Y9**	**Y10**	**Y11**	**Y12**	**Y13**	**Y14**	**Y15**	**Y16**	**Y17**	**Y18**
Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Investment	-1.409.600						-400.000						-400.000						
Residual value							70.000						70.000						140.000
Annual revenues		1.732.500	1.732.500	1.732.500	1.732.500	1.732.500	1.732.500	1.732.500	1.732.500	1.732.500	1.732.500	1.732.500	1.732.500	1.732.500	1.732.500	1.732.500	1.732.500	1.732.500	1.732.500
Annual operating & maintenance costs		-485.636	-486.221	-486.831	-487.465	-488.126	-488.815	-485.636	-486.221	-486.831	-487.465	-488.126	-488.815	-485.636	-486.221	-486.831	-487.465	-488.126	-488.815
Net pre-tax cash flow	-1.409.600	1.246.864	1.246.279	1.245.669	1.245.035	1.244.374	913.685	1.246.864	1.246.279	1.245.669	1.245.035	1.244.374	913.685	1.246.864	1.246.279	1.245.669	1.245.035	1.244.374	1.383.685
Cumulative pre-tax cash flow	-1.409.600	-162.736	1.083.542	2.329.212	3.574.247	4.818.620	5.732.306	6.979.169	8.225.448	9.471.117	10.716.152	11.960.526	12.874.211	14.121.075	15.367.353	16.613.023	17.858.058	19.102.432	20.486.117
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Pre-tax NPV	8.538.956																		
Pre-tax IRR	87,93%																		
Pre-tax payback (years)	1,13																		
INCOME TAX RATE OF 25%																			
Depreciation		-126.960	-114.264	-102.838	-92.554	-83.298	-74.969	-100.472	-90.425	-81.382	-73.244	-65.920	-59.328	-86.395	-77.755	-69.980	-62.982	-56.684	-51.015
Book value		1.282.640	1.168.376	1.065.538	972.985	889.686	814.717	1.044.246	953.821	872.439	799.195	733.276	673.948	917.553	839.798	769.818	706.836	650.153	599.137
Taxable income		1.119.904	1.132.015	1.142.832	1.152.481	1.161.075	1.168.717	1.146.392	1.155.854	1.164.287	1.171.791	1.178.454	1.184.358	1.160.469	1.168.523	1.175.690	1.182.053	1.187.690	733.533
Income tax		-279.976	-283.004	-285.708	-288.120	-290.269	-292.179	-286.598	-288.964	-291.072	-292.948	-294.614	-296.089	-290.117	-292.131	-293.922	-295.513	-296.923	-183.383
Net after-tax cash flow	-1.409.600	966.888	963.275	959.962	956.915	954.105	621.506	960.266	957.315	954.598	952.087	949.760	617.596	956.746	954.148	951.747	949.522	947.451	1.200.302
Cumulative after-tax cash flow	-1.409.600	-442.712	520.563	1.480.524	2.437.439	3.391.544	4.013.050	4.973.315	5.930.631	6.885.228	7.837.315	8.787.076	9.404.671	10.361.418	11.315.566	12.267.313	13.216.834	14.164.286	15.364.588
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
After-tax NPV	6.190.707																		
After-tax IRR	67,54%																		
After-tax payback (years)	1,46																		
ALTERNATIVELY: FLAT INCOME TAX OF 7,500 NPR																			
Income tax		-7500	-7500	-7500	-7500	-7500	-7500	-7500	-7500	-7500	-7500	-7500	-7500	-7500	-7500	-7500	-7500	-7500	-7500
Net after-tax cash flow	-1.409.600	1.239.364	1.238.779	1.238.169	1.237.535	1.236.874	906.185	1.239.364	1.238.779	1.238.169	1.237.535	1.236.874	906.185	1.239.364	1.238.779	1.238.169	1.237.535	1.236.874	1.376.185
Cumulative after-tax cash flow	-1.409.600	-170.236	1.068.542	2.306.712	3.544.247	4.781.120	5.687.306	6.926.669	8.165.448	9.403.617	10.641.152	11.878.026	12.784.211	14.023.575	15.262.353	16.500.523	17.738.058	18.974.932	20.351.117
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
After-tax NPV	8.477.446																		
After-tax IRR	87,40%																		
After-tax payback (years)	1,14																		

The results of the financial assessment appear in Table 28. With a pre-tax NPV of more than 8.5 million NPR (at a discount rate of 10%) and a corresponding IRR of almost 88%, the profitability of this investment is impressive. A tax rate of 25% lowers these figures and prolongs the payback period from 1.13 to 1.46 years but cannot threaten overall profitability.

To investigate the competitiveness of this vehicle, it was decided to assess the financial performance of a brand new pick-up truck, typical for this kind of operation in the city. A petrol driven truck was selected, although a diesel run model also exist. The purchase price and operating costs of such a vehicle appear in Table 29. Its deployment and average annual earnings were assumed to be identical to those of the 3W under assessment.

New pick-up truck - Investor's perspective - Input values				
Category	**Parameter**	**Value**	**Units**	**Comments**
General info	Year built	2022		
	Payload capacity	750	kg	Officially only 500 kg (bluebook)
Propulsion	ICE	Petrol		Diesel-powered trucks also exist
	Fuel capacity	26	lt	
Capital cost	Investment cost	1.975.000	NPR	End of 2022 price of a new vehicle
	Expected useful life	18	years	Taken equal to the life of the new 3-wheeler
	Residual value	70.000	NPR	Assumption based on scrap value
	Depreciation schedule	10%		Per year
Operating profile	Average length of trip	20	km	
	Paid trips/day	3,5	trips/day	
	Total distance/day	70	km/day	(=C12*C11)
	Operating days/year	330	days/year	
Yearly	Total operating cost	843.875	NPR/year	(=sum(C16:C18)+C22+C25+C395)
	* Vehicle road tax	24.000	NPR/year	
	* Insurance	18.750	NPR/year	
	* Personnel cost	297.300	NPR/year	(=(C19+C20)*12+C21)
	- Basic monthly salary	20.000	NPR/month	
	- Monthly allowance	4.000	NPR/month	
	- Yearly bonus	9.300	NPR/year	
	* Fuel cost	348.425	NPR/year	(=C14*C13*C23*C24)
	- Specific energy consumption	0,083	lt/km	On the assumption of 12 km per liter
	- Fuel price	181	NPR/lt	As of 12 December 2022
	* Maintenance cost	118.900	NPR/year	(=sum(C26:C38))
	- Tires	20.000	NPR/year	
	- Brake shoes	12.000	NPR/year	
	- Dent paint	8.000	NPR/year	
	- Suspension	3.000	NPR/year	
	- Wiring	4.000	NPR/year	
	- Headlights, tail lights	4.000	NPR/year	
	- Differential crown gear	6.000	NPR/year	
	- Fuses	1.200	NPR/year	
	- Display system	2.000	NPR/year	
	- Throttle pedal	1.200	NPR/year	
	- Battery change	3.500	NPR/year	
	- Engine service	54.000	NPR/year	(oil change, etc.)
	- Other maintenance costs	0	NPR/year	
	* Other	36.500	NPR/year	(=sum(C40:C42))
	- Vehicle parking	18.000	NPR/year	(=1.500 NPR per month)
	- Vehicle cleaning	18.000	NPR/year	(=1.500 NPR per month)
	- Driver's license	500	NPR/year	
Yearly revenues	Total revenues	1.732.500	NPR/year	(=C14*C12*C44)
	Charge per trip	1.500	NPR/trip	
Income tax	Income tax rate	25%		

Table 29. Input values for assessing a new pick-up truck

Table 30. Financial performance of a new pick-up truck

New pick-up truck - Investor's perspective - Calculations																			
Discount rate	10%																		
	Y0	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11	Y12	Y13	Y14	Y15	Y16	Y17	Y18
Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Investment	-1.975.000																		
Residual value																			70.000
Annual revenues		1.732.500	1.732.500	1.732.500	1.732.500	1.732.500	1.732.500	1.732.500	1.732.500	1.732.500	1.732.500	1.732.500	1.732.500	1.732.500	1.732.500	1.732.500	1.732.500	1.732.500	1.732.500
Annual operating & maintenance costs		-843.875	-843.875	-843.875	-843.875	-843.875	-843.875	-843.875	-843.875	-843.875	-843.875	-843.875	-843.875	-843.875	-843.875	-843.875	-843.875	-843.875	-843.875
Net pre-tax cash flow	-1.975.000	888.625	888.625	888.625	888.625	888.625	888.625	888.625	888.625	888.625	888.625	888.625	888.625	888.625	888.625	888.625	888.625	888.625	958.625
Cumulative pre-tax cash flow	-1.975.000	-1.086.375	-197.750	690.875	1.579.500	2.468.125	3.356.750	4.245.375	5.134.000	6.022.625	6.911.250	7.799.875	8.688.500	9.577.125	10.465.750	11.354.375	12.243.000	13.131.625	14.090.250
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Pre-tax NPV	5.325.570																		
Pre-tax IRR	44,94%																		
Pre-tax payback (years)	2,22																		
Depreciation		-190.500	-171.450	-154.305	-138.875	-124.987	-112.488	-101.240	-91.116	-82.004	-73.804	-66.423	-59.781	-53.803	-48.423	-43.580	-39.222	-35.300	-31.770
Book value		1.784.500	1.613.050	1.458.745	1.319.871	1.194.883	1.082.395	981.156	890.040	808.036	734.232	667.809	608.028	554.225	505.803	462.223	423.000	387.700	355.930
Taxable income		698.125	717.175	734.320	749.751	763.638	776.137	787.385	797.509	806.621	814.821	822.202	828.844	834.822	840.202	845.045	849.403	853.325	570.925
Income tax		-174.531	-179.294	-183.580	-187.438	-190.909	-194.034	-196.846	-199.377	-201.655	-203.705	-205.550	-207.211	-208.706	-210.051	-211.261	-212.351	-213.331	-142.731
Net after-tax cash flow	-1.975.000	714.094	709.331	705.045	701.187	697.716	694.591	691.779	689.248	686.970	684.920	683.075	681.414	679.919	678.574	677.364	676.274	675.294	815.894
Cumulative after-tax cash flow	-1.975.000	-1.260.906	-551.575	153.470	854.657	1.552.373	2.246.964	2.938.742	3.627.990	4.314.960	4.999.879	5.682.954	6.364.368	7.044.287	7.722.862	8.400.226	9.076.500	9.751.794	10.567.688
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
After-tax NPV	3.748.128																		
After-tax IRR	35,49%																		
After-tax payback (years)	2,78																		

As shown in Table 30, the new pick-up truck constitutes a sound investment as well. Its financial performance, however, falls short of the 3W's one due to higher investment and annual operating costs. Thus, it can be concluded that the new cargo e3W design outperforms successful 4W models in the marketplace.

In addition, the financial indicators of the new design exhibit astonishing robustness. Even when investment cost is raised from about 1.4 to 3.0 million NPR, the expected NPV remains above 6.9 million NPR. Similarly, a drop in earnings by 50% results in a still positive NPV of 1.4 million NPR and an IRR of 24.49% (Figure 27). Investment must be doubled at 2.8 million NPR and at the same time annual revenues must be halved at 866.250 NPR before the project's NPV drops to 25.000 NPR (IRR=10.14%).

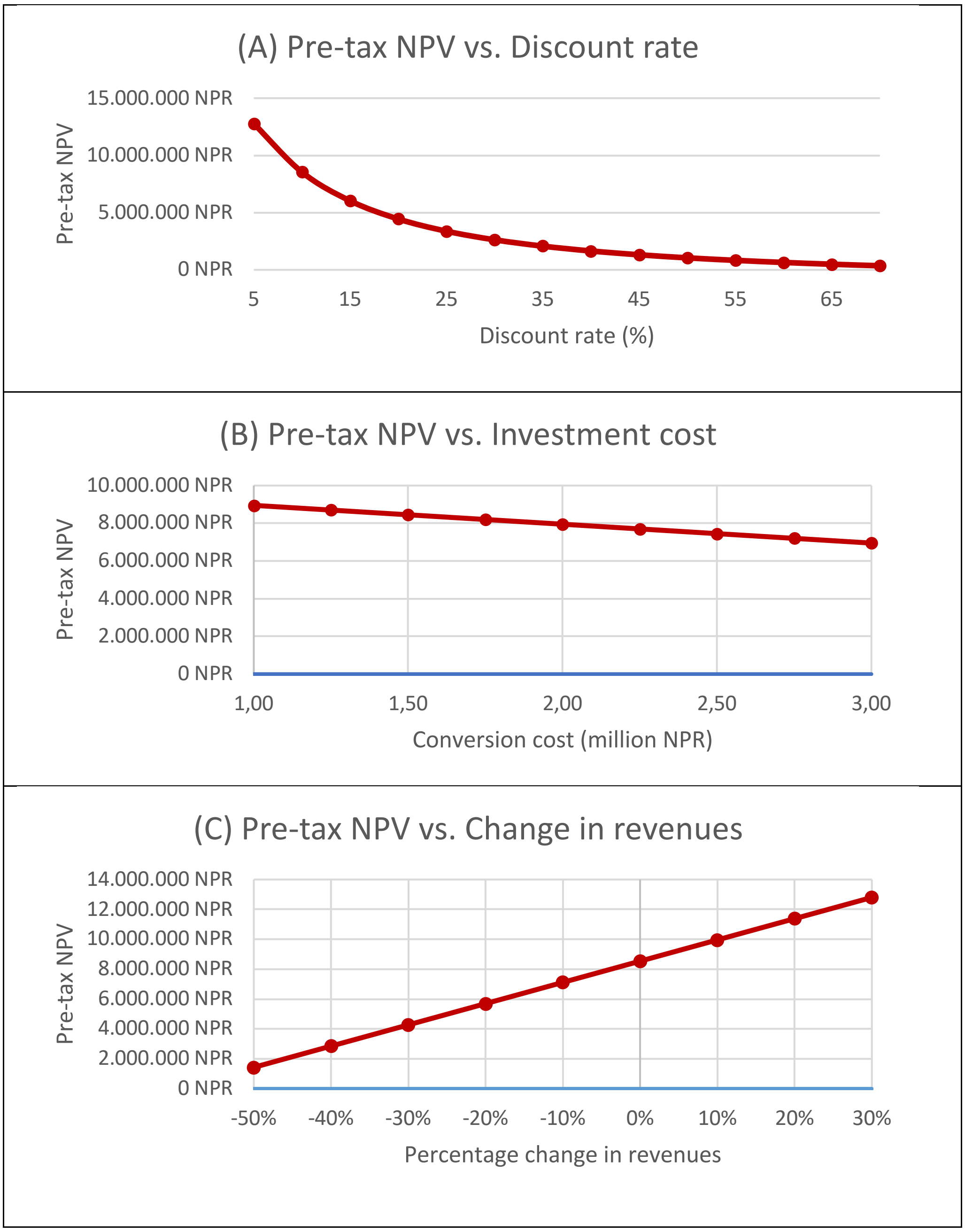


Figure 27. New cargo e3W design: Sensitivity analysis on pre-tax NPV

3.8.2. EFFECT ON EMISSIONS AND OTHER ENVIRONMENTAL ATTRIBUTES

GHG emissions

Given that the newly designed cargo e3W is expected to produce exactly the same transport work with the pick-up truck, and under the assumption that all electricity used by the e3W will be generated exclusively through renewable sources, the emissions of the pick-up truck reflect the emissions abated. These emissions have been calculated for the same pick-up truck in relation to the remodelled Safa Tempo – cargo vehicle (Section 3.6.2). Only the result is repeated here for reasons of completeness.
Under the assumed deployment, one unit of the newly designed e3W is expected to save 5.78 tonnes of CO2 emissions per year.

NOx emissions

Similarly, one unit of the new cargo e3W is expected to save 26.49 kg of NOx emissions annually.

PM2.5 emissions

The mass of abated PM2.5 emissions annually per unit of the newly designed cargo 3-wheeler is 36.42 kg.

Noise

At the time of drafting this document, the noise measurements of the newly designed e3W had not been finalised pending licensing of the demo vehicle.

3.9. CONVERTED 4-WHEELER – WASTE COLLECTION

3.9.1. FINANCIAL VIABILITY

This demo component concerns the activity of primary waste collection, defined as the collection and carriage of waste from households to a consolidation site using light vehicles. Larger trucks are used for further moving the waste to landfills. Primary collection is undertaken by the municipalities in the Kathmandu valley and does not earn any revenues directly.[11] As such, financial viability will be assessed through the cost effectiveness ratio (CER) indicator.

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. Its purchase price in 1917 was 750,000 NPR, which is equivalent to about 969,000 NPR of 2022. Its expected useful life is 12 years. Its annualised total cost (capital and operational) is estimated at about 827,000 NPR. Assuming full utilisation of the vehicle, a volume of 1,505 cu.m. of waste can be collected per year, bringing the CER to 549.16 NPR/cu.m. (refer to Table 31).

Compared against this vehicle, the modular light 3W design of Sections 3.7 and 3.8 (properly fitted for waste collection) proved financially unsustainable (CER value of 917.85 NPR/cu.m.) due to its low volumetric capacity (2.18 cu.m.) despite its higher payload potential (500 kg)[12]. An alternative solution was needed.

11 Although the valley residents do pay a fee for waste collection, this reflects the entire operation and cannot be split into the specific activities involved.
12 Due to its low density, waste is considered a volume-bound cargo.

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

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 must be replaced with a new one, enabling operations for a total of 12 years. Table 32 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).

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)

Table 32. CER calculation for the waste collector (converted 4-wheeler)

The sensitivity analysis of Figure 28 shows that the percentage difference in CER values (ΔCER) shrinks with the discount rate. This is due to the higher capital cost of the converted 4W solution. It becomes zero only when the discount rate increases to 28.17%, which is a high value, particularly when expressed in real terms. As expected, ΔCER also drops with the investment cost. However, the amount invested must be inflated by 44.6% to 2.97 million NPR before the difference disappears.

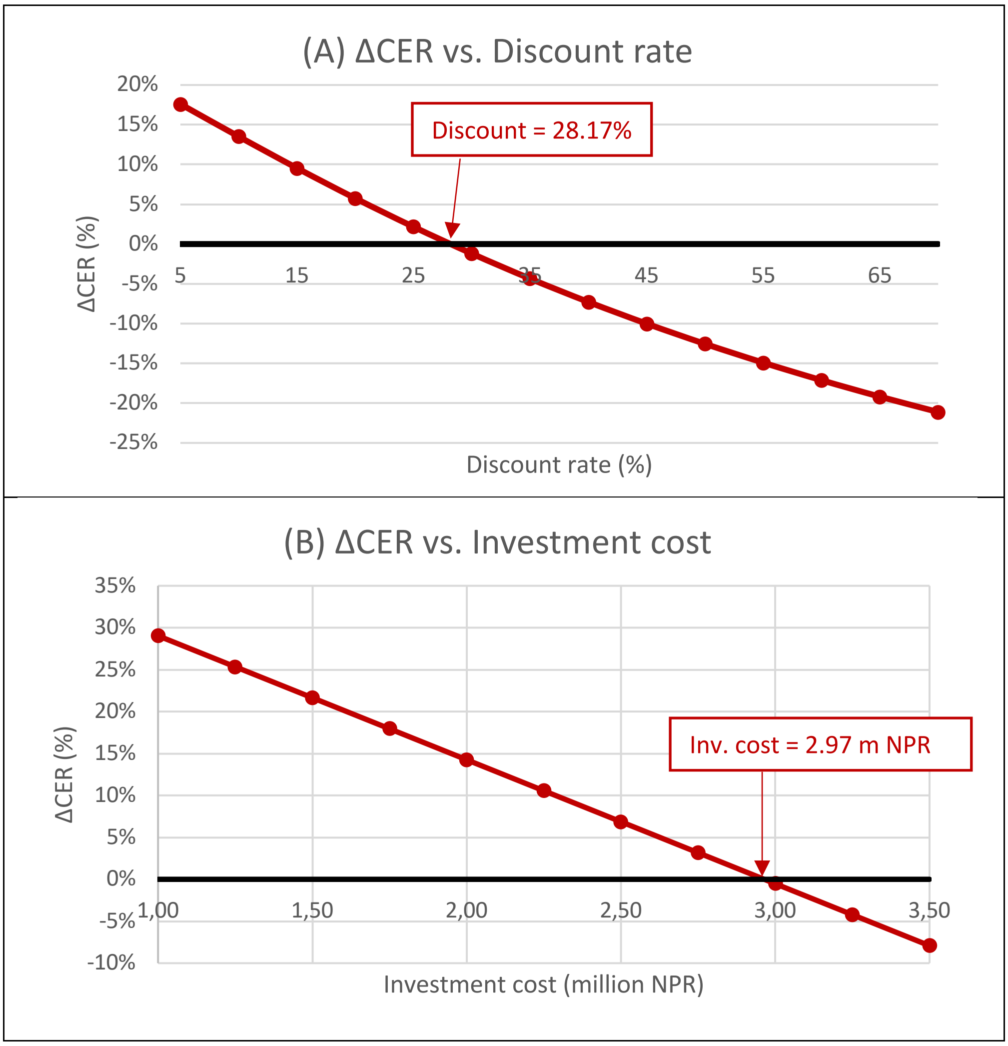


Figure 28. Converted 4W – Waste collector: Sensitivity analysis on ΔCER

3.9.2. EFFECT ON EMISSIONS AND OTHER ENVIRONMENTAL ATTRIBUTES

Although the converted 4W was benchmarked against the petrol-driven 3W for the financial performance, it will be compared to a petrol-driven pick-up truck when it comes to environmental attributes. The reasons are twofold: (i) there exist very few petrol-driven 3W deployed in waste collection, and (ii) once converted into a waste collector, the truck will no longer generate the emissions it used to do under its previous deployment. 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 (Section 3.6.2). 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.

GHG emissions

Assuming a well-to-wheel (WtW) CO2 factor of 3,000 gr/lt (e-Mob default value), the above estimated amount of fuel corresponds to 4.00 tonnes of CO2 emissions saved per unit of converted 4-wheeler.

NOx emissions

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.

PM2.5 emissions

Similarly, the PM2.5 emissions factor for this type of fuel and vehicle is 18.92 gr/lt (Das et al., 2022). The mass of abated PM2.5 emissions annually per unit of converted 4W then becomes 25.23 kg.

Noise

At the time of drafting this document, the noise measurements of the converted 4W had not been finalised pending completion of the demo vehicle.

3.10. PICK-UP TRUCK CONVERSION

3.10.1. FINANCIAL VIABILITY

This component concerns the conversion of an existing petrol-driven pick-up truck into an EV. A 15 kWh lithium-iron-phosphate (LFP) battery and a new drive train will be installed on the old vehicle, built in 2007, which has a payload capacity of 750 kg (although the license is restricted to a maximum freight load of 500 kg).

Investor's perspective

As previously, this assessment concerns the scenario of an investor directly buying the converted vehicle from the manufacturer. The expected battery life restricts the useful life of the vehicle to 6 years, after which, the initial investment of 1.93 million NPR (about €13,560) will only be worth 150,000 NPR. The input values for its financial assessment appear in Table 33. As with previous cases concerning pick-up trucks, the vehicle is expected to be operational for 330 days per year and perform daily an average of 3.5 paid trips of 20 km each. At an average charge of 1,500 NPR per trip, the yearly revenues are estimated at about 1.73 million NPR.

Under these assumptions the investment looks lucrative with a pre-tax NPV of almost 3.8 million NPR (at 10% discount rate), an IRR of almost 64% and a payback period of less than 18 months (refer to Table 34). Neither the sensitivity analysis of Figure 29 generates any concerns. The NPV remains above 2.7 million NPR even when the conversion cost increases to 3 million NPR (more than 55% above the estimated level), while it remains marginally positive even when revenues are reduced by 50%.

Converted pick-up truck - Investor's perspective - Input values				
Category	**Parameter**	**Value**	**Units**	**Comments**
General info	Year built	2007		
	Payload capacity	750	kg	Officially only 500 kg (bluebook)
Propulsion	Electric	LFP		
	Battery capacity	15	kWh	Only 80% (=12 kWh) can be used before recharging
Capital cost	Investment cost	1.927.000	NPR	(=sum(C8:C10))
	- Old vehicle	450.000	NPR	
	- Drive train	702.000	NPR	
	- Battery pack	775.000	NPR	
	Expected useful life	6	years	Based on the charging cycles of the battery
	Residual value	150.000	NPR	
	Depreciation schedule	10%		Per year
Operating profile	Average length of trip	20	km	
	Paid trips/day	3,5	trips/day	
	Total distance/day	70	km/day	(=C15*C14)
	Operating days/year	330	days/year	
Yearly operating	Total operating cost	437.270	NPR/year	(=sum(C19:C21)+C25+C29+C43)
	* Road tax, license renewal & insp.	24.000	NPR/year	
	* Insurance	11.000	NPR/year	
	* Personnel cost	297.300	NPR/year	(=(C22+C23)*12+C24)
	- Basic monthly salary	20.000	NPR/month	
	- Monthly allowance	4.000	NPR/month	
	- Yearly bonus	9.300	NPR/year	
	* Electricity cost	27.720	NPR/year	(=C16*C17*C26*C28)
	- Specific energy consumption	0,120	kWh/km	On the assumption of 100 km per 12 kWh
	- Battery efficiency	100,000	%	Average annual drop of 4%
	- Fuel price	10	NPR/kWh	Price applicable in registered charging stattions
	* Maintenance cost	40.750	NPR/year	(=sum(C30:C42))
	- Tires	10.000	NPR/year	
	- Brake shoes	12.000	NPR/year	
	- Dent paint	8.000	NPR/year	
	- Suspension	3.000	NPR/year	
	- Wiring	0	NPR/year	
	- Headlights, tail lights	4.000	NPR/year	
	- Differential crown gear	0	NPR/year	
	- Fuses	500	NPR/year	
	- Display system	2.500	NPR/year	
	- Throttle pedal	750	NPR/year	
	- Battery change	0	NPR/year	
	- Engine service	0	NPR/year	
	- Other maintenance costs	0	NPR/year	
	* Other	36.500	NPR/year	(=sum(C44:C46))
	- Vehicle parking	18.000	NPR/year	(=1.500 NPR per month)
	- Vehicle cleaning	18.000	NPR/year	(=1.500 NPR per month)
	- Driver's license	500	NPR/year	
Yearly revenues	Total revenues	1.732.500	NPR/year	(=C17*C15*C48)
	Charge per trip	1.500	NPR/trip	
Income tax	Income tax rate	25%		

Table 33. Input values for assessing the converted pick-up truck (Investor’s perspective)

Converted pick-up truck - Inspector's perspective - Calculations							
Discount rate	10%						
	Y0	Y1	Y2	Y3	Y4	Y5	Y6
Year	2022	2023	2024	2025	2026	2027	2028
Investment	-1.927.000						
Residual value							150.000
Annual revenues		1.732.500	1.732.500	1.732.500	1.732.500	1.732.500	1.732.500
Annual operating & maintenance costs		-438.425	-439.628	-440.881	-442.187	-443.547	-444.963
Net pre-tax cash flow	-1.927.000	1.294.075	1.292.872	1.291.619	1.290.313	1.288.953	1.437.537
Cumulative pre-tax cash flow	-1.927.000	-632.925	659.947	1.951.565	3.241.879	4.530.832	5.968.369
Year	0	1	2	3	4	5	6
Pre-tax NPV	3.781.425						
Pre-tax IRR	63,87%						
Pre-tax payback (years)	1,49						
Depreciation		-177.700	-159.930	-143.937	-129.543	-116.589	-104.930
Book value		1.749.300	1.589.370	1.445.433	1.315.890	1.199.301	1.094.371
Taxable income		1.116.375	1.132.942	1.147.682	1.160.770	1.172.364	238.236
Income tax		-279.094	-283.235	-286.920	-290.192	-293.091	-59.559
Net after-tax cash flow	-1.927.000	1.014.981	1.009.636	1.004.698	1.000.121	995.862	1.377.978
Cumulative after-tax cash flow	-1.927.000	-912.019	97.618	1.102.316	2.102.437	3.098.299	4.476.276
Year	0	1	2	3	4	5	6
After-tax NPV	2.664.246						
After-tax IRR	48,29%						
After-tax payback (years)	1,90						

Table 34. Financial indicators for the converted pick-up truck (Investor's perspective)

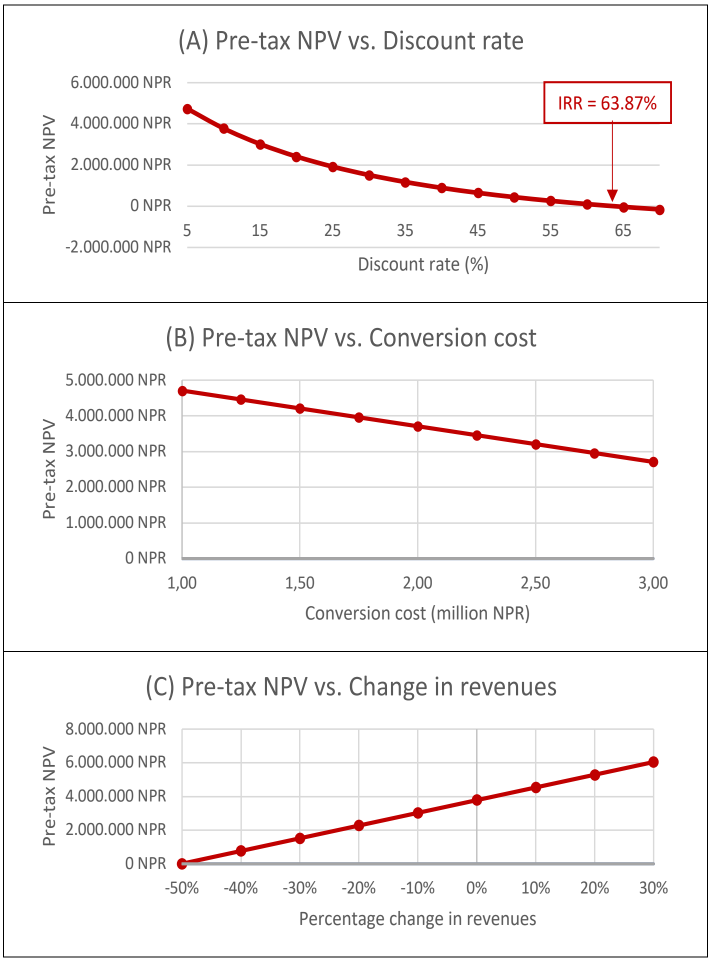


Figure 29. Converted pick-up truck: Sensitivity analysis on NPV

Operator's perspective

The purpose of this section is to investigate whether the operators of the existing pick-up trucks have any incentive to proceed with this conversion. At the assumed second-hand price of 450,000 NPR (Table 33), the employment of the vehicle for 6 years under an operating profile identical to this of Table 29, is expected to generate almost 3.5 million NPR, an astonishing return equivalent to an IRR of 198% (Table 35).

Existing pick-up truck - Operator's perspective - BEFORE - Calculations							
Discount rate	10%						
	Y0	Y1	Y2	Y3	Y4	Y5	Y6
Year	2022	2023	2024	2025	2026	2027	2028
Investment	-450.000						
Residual value							100.000
Annual revenues		1.732.500	1.732.500	1.732.500	1.732.500	1.732.500	1.732.500
Annual operating & maintenance costs		-839.793	-839.793	-839.793	-839.793	-839.793	-839.793
Net pre-tax cash flow	-450.000	892.707	892.707	892.707	892.707	892.707	992.707
Cumulative pre-tax cash flow	-450.000	442.707	1.335.415	2.228.122	3.120.829	4.013.537	5.006.244
Year	0	1	2	3	4	5	6
Pre-tax NPV	3.494.421						
Pre-tax IRR	198,16%						
Pre-tax payback (years)	0,50						
Depreciation		-35.000	-31.500	-28.350	-25.515	-22.964	-20.667
Book value		415.000	383.500	355.150	329.635	306.672	286.004
Taxable income		857.707	861.207	864.357	867.192	869.744	686.036
Income tax		-214.427	-215.302	-216.089	-216.798	-217.436	-171.509
Net after-tax cash flow	-450.000	678.281	677.406	676.618	675.909	675.271	821.198
Cumulative after-tax cash flow	-450.000	228.281	905.686	1.582.304	2.258.213	2.933.485	3.754.683
Year	0	1	2	3	4	5	6
After-tax NPV	2.579.302						
After-tax IRR	150,20%						
After-tax payback (years)	0,66						

Table 35. Profitability of an existing pick-up truck – Before conversion (operator's perspective)

When the NPVs of Table 35 enter the financial assessment of Table 36 as an additional cost (foregone profit), accompanied by a simultaneous reduction of total investment by the market price of the vehicle that now doesn't have to be purchased, the overall profitability of the conversion project is achieved. Given that the 3.5 million NPR of the previous operation has already been internalised, the NPV of Table 36 is an additional expected profit. Thus, the conversion project is still meaningful despite the enormous profits of the existing operation.

It is worth mentioning that, although the second-hand price of the existing vehicle influences the profitability of the project from the investor's perspective (a higher price reduces expected profits), it has no effect on the project's profits from the operator's perspective, as it now constitutes an internal variable.

Converted pick-up truck - Operator's perspective - AFTER - Calculations							
Discount rate	10%						
	Y0	Y1	Y2	Y3	Y4	Y5	Y6
Year	2022	2023	2024	2025	2026	2027	2028
Investment	-4.971.421						
Residual value							150.000
Annual revenues		1.732.500	1.732.500	1.732.500	1.732.500	1.732.500	1.732.500
Annual operating & maintenance costs		-438.425	-439.628	-440.881	-442.187	-443.547	-444.963
Net pre-tax cash flow	-4.971.421	1.294.075	1.292.872	1.291.619	1.290.313	1.288.953	1.437.537
Cumulative pre-tax cash flow	-4.971.421	-3.677.346	-2.384.474	-1.092.855	197.458	1.486.411	2.923.948
Year	0	1	2	3	4	5	6
Pre-tax NPV	737.004						
Pre-tax IRR	14,86%						
Pre-tax payback (years)	3,85						
Investment adjustment due to tax	-4.056.302						
Depreciation		-161.300	-145.170	-130.653	-117.588	-105.829	-95.246
Book value		1.601.704	1.456.534	1.325.880	1.208.292	1.102.463	1.007.217
Taxable income		1.132.775	1.147.701	1.160.965	1.172.725	1.183.124	335.074
Income tax		-283.194	-286.925	-290.241	-293.181	-295.781	-83.768
Net after-tax cash flow	-4.056.302	1.010.881	1.005.947	1.001.377	997.132	993.172	1.353.768
Cumulative after-tax cash flow	-4.056.302	-3.045.420	-2.039.474	-1.038.097	-40.965	952.208	2.305.976
Year	0	1	2	3	4	5	6
After-tax NPV	508.295						
After-tax IRR	14,03%						
After-tax payback (years)	4,04						

Table 36. Overall profitability of the conversion project (operator's perspective)

3.10.2. EFFECT ON EMISSIONS AND OTHER ENVIRONMENTAL ATTRIBUTES

The converted truck will replace an existing pick-up truck in the latter's daily operations. Under the assumption that all electricity used by the converted vehicle will be generated exclusively through renewable sources, the emissions of the pick-up truck reflect the emissions abated. These emissions have been calculated for the same operating profile in relation to the remodelled Safa Tempo – cargo vehicle (Section 3.6.2). As such, the calculations are omitted and solely the results are repeated here for reasons of completeness.

GHG emissions

Under the assumed deployment, one unit of the converted vehicle is expected to save 5.78 tonnes of CO2 emissions per year.

NOx emissions

Similarly, one unit of the converted truck is expected to save 26.49 kg of NOx emissions annually.

PM2.5 emissions

The mass of abated PM2.5 emissions annually per unit of the converted pick-up truck is 36.42 kg.

Noise

Until the time of drafting this document, the local team was not able to obtain noise measurements of the converted truck. However, the interviewed driver reported a significant improvement compared to the existing petrol-driven pick-up truck in terms of noise, which is equivalent to a score of 5.

3.10.3. EFFECT ON SERVICE QUALITY

Only one driver tested the converted truck during the demonstration period. His scoring appears in Table 37.

Score	Description	Respondents		Overall score
		Number	Share	
E.13	**Perceived comfort**			
1	OLD solution much more comfortable than NEW one		0,00%	
2	OLD solution more comfortable than NEW one		0,00%	
3	No difference between the two solutions	1	100,00%	
4	NEW solution more comfortable than OLD one		0,00%	
5	NEW solution much more comfortable than OLD one		0,00%	
	Total	**1**	**100,00%**	**3,00**
E.14	**Perceived drivability (professional drivers)**			
1	OLD solution much easier to drive than NEW one		0,00%	
2	OLD solution easier to drive than NEW one		0,00%	
3	No difference between the two solutions		0,00%	
4	NEW solution easier to drive than OLD one		0,00%	
5	NEW solution much easier to drive than OLD one	1	100,00%	
	Total	**1**	**100,00%**	**5,00**
E.16	**Perceived chargeability (professional drivers)**			
1	OLD solution much easier to charge/refuel than NEW one		0,00%	
2	OLD solution easier to charge/refuel than NEW one	1	100,00%	
3	No difference between the two solutions		0,00%	
4	NEW solution easier to charge/refuel than OLD one		0,00%	
5	NEW solution much easier to charge/refuel than OLD one		0,00%	
	Total	**1**	**100,00%**	**2,00**
E.17	**Perceived safety**			
1	OLD solution much safer than NEW one		0,00%	
2	OLD solution safer than NEW one		0,00%	
3	No difference between the two solutions	1	100,00%	
4	NEW solution safer than OLD one		0,00%	
5	NEW solution much safter than OLD one		0,00%	
	Total	**1**	**100,00%**	**3,00**

Table 37. Service quality indicators for the converted pick-up truck

3.11. NEWLY DESIGNED E-SHUTTLE VAN

Lalitpur municipality currently operates an open-type shuttle van on the Pulchwok to Mangalbazar route. The vehicle is equipped with a 5 kWh lithium-ion battery and has a capacity of 8 passengers. It is used for transporting elderly/disabled people and the service is provided free of charge. A slightly smaller (for up to 6 passengers) but closed-type van was thought to be suitable for transporting tourists to the Bhaktapur historical sites either at a fare or not. The design of such an e-shuttle van is the purpose of this demo component.

3.11.1. FINANCIAL VIABILITY

The newly designed van will carry a lithium-iron-phosphate (LFP) 15 kWh battery enabling a range of more than 100 km per day. Purchased at a price of 2,525,000 NPR (about €17,820 at the 31/12/2022 exchange rate), the vehicle is expected to be operational for 12 years, if the battery is replaced after 6 years at an additional cost of 145,000 NPR (after subtracting the residual value of the old battery).

Assuming an average ridership of 100 passengers per day, and a fare of 20 NPR per passenger, the operation will generate annual revenues of 640,000 NPR, which is sufficient to cover only the operating expenses of about 573,700 NPR (refer to Table 39). The financial indicators of Table 38 confirm the loss making prospects when the capital costs enter the calculation.

Table 38. Financial performance of the e-shuttle van in a revenue-earning scenario

New design shuttle van - Investor's perspective - Calculations													
Discount rate	10%												
	Y0	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11	Y12
Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Investment	-2.525.000						-800.000						
Residual value							105.000						355.000
Annual revenues		640.000	640.000	640.000	640.000	640.000	640.000	640.000	640.000	640.000	640.000	640.000	640.000
Annual operating & maintenance costs		-573.711	-573.711	-573.711	-573.711	-573.711	-573.711	-573.711	-573.711	-573.711	-573.711	-573.711	-573.711
Net pre-tax cash flow	-2.525.000	66.289	66.289	66.289	66.289	66.289	-628.711	66.289	66.289	66.289	66.289	66.289	421.289
Cumulative pre-tax cash flow	-2.525.000	-2.458.711	-2.392.421	-2.326.132	-2.259.842	-2.193.553	-2.822.264	-2.755.974	-2.689.685	-2.623.396	-2.557.106	-2.490.817	-2.069.527
Year	0	1	2	3	4	5	6	7	8	9	10	11	12
Pre-tax NPV	-2.352.520												
Pre-tax IRR	-13,11%												
Pre-tax payback (years)	48,57												
INCOME TAX RATE OF 25%													
Depreciation		-217.000	-195.300	-175.770	-158.193	-142.374	-128.136	-184.823	-176.840	-159.156	-143.241	-128.917	-116.025
Book value		2.308.000	2.112.700	1.936.930	1.778.737	1.636.363	1.508.227	2.123.404	1.946.564	1.787.407	1.644.167	1.515.250	1.399.225
Taxable income		-150.711	-129.011	-109.481	-91.904	-76.084	-61.847	-118.533	-110.551	-92.867	-76.951	-62.627	-1.093.961
Income tax		0	0	0	0	0	0	0	0	0	0	0	0
Net after-tax cash flow	-2.525.000	66.289	66.289	66.289	66.289	66.289	-628.711	66.289	66.289	66.289	66.289	66.289	421.289
Cumulative after-tax cash flow	-2.525.000	-2.458.711	-2.392.421	-2.326.132	-2.259.842	-2.193.553	-2.822.264	-2.755.974	-2.689.685	-2.623.396	-2.557.106	-2.490.817	-2.069.527
Year	0	1	2	3	4	5	6	7	8	9	10	11	12
After-tax NPV	-2.352.520												
After-tax IRR	-13,11%												
After-tax payback (years)	48,57												

New design shuttle van - Investor's perspective - Input values				
Category	**Parameter**	**Value**	**Units**	**Comments**
General info	Year built	2023		
	Passenger capacity	6		
Propulsion	Battery type	LPF		
	Battery size	15	kWh	Only 80% (=12 kWh) can be used before recharging
	Number of batteries	1		
Capital cost	Purchase price	2.525.000	NPR	(=sum(C9:C11))
	- Manufacturing cost	1.200.000		
	- Cost of drive train	525.000		
	- Cost of battery	800.000		
	Expected useful life	12	years	Based on the life expectancy of the battery (2 cycles of 6 years)
	Residual value	355.000	NPR	(=C14+C15)
	- Body	250.000		After 12 years (scrap value)
	- Battery	105.000		After 6 years (on the assumption of 7.000NPR/kWh)
	Depreciation schedule	10%		Per year (Declining balance method)
Operational profile	Route	Bhaktapur		Tertiary roads
	Length of round trip	10	km	
	Round trips/day	10	trips/day	
	Total distance/day	100	km/day	(=C19*C18)
	Operating days/year	320	days/year	
	Passengers/day	100	pax	
	Chargings/day	1		Overnight charging
Yearly	Total operating cost	573.711	NPR/year	(=sum(C25:C30)+C34+C38+C50)
	* Licencing/renewal	5.000	NPR/year	
	* Route permit	2.000	NPR/year	
	* Vehicle road tax	0	NPR/year	Run by a municipality
	* Technical inspection	2.500		
	* Insurance	25.000	NPR/year	
	* Personnel cost	373.000	NPR/year	(=(C31+C32)*12+C33)
	- Basic monthly salary	25.000	NPR/month	
	- Monthly allowance	4.000	NPR/month	
	- Yearly bonus	25.000	NPR/year	
	* Electricity cost	22.841	NPR/year	Equivalent annual cost
	- Specific energy consumption	0,092	kWh/km	On the assumption that the max range of a 12kWh battery is 130 km.
	- Battery efficiency	100,00	%	Drops by 3% every year
	- Electricity tariff	7	NPR/kWh	Special tariff for EVs
	* Maintenance cost	78.550	NPR/year	(=sum(C39:C49))
	- Tires	20.000	NPR/year	40.000 NPR every two years.
	- Brake shoes	3.500	NPR/year	
	- Dent paint	20.000	NPR/year	60.000 NPR every three years.
	- Suspension	4.500	NPR/year	
	- Wiring	4.500	NPR/year	
	- Headlights, tail lights	3.500	NPR/year	
	- Independent rear axle	10.000	NPR/year	
	- Fuses	1.550	NPR/year	
	- Display system	5.000	NPR/year	
	- Throttle pedal	5.000	NPR/year	
	- Motor servicing	1.000	NPR/year	
	* Other	64.820	NPR/year	(=sum(C51:C53))
	- Vehicle parking	24.000	NPR/year	(=2.000 NPR per month)
	- Vehicle cleaning	40.800	NPR/year	(=3.400 NPR per month)
	- Other	20	NPR/year	Stationary & ticketing
Yearly revenues	Total revenues	640.000	NPR/year	(=C21*C22*C55)
	Ticket fare/passenger	20	NPR/pax	
Income tax	Income tax rate	25%		
		Calculation of Cost Effectiveness Ratio (CER)		
Annualized cost	Discount rate	10%		
	Capital	411.553	NPR/year	(=(C8+(C11-C15)/(1+C59)^(C12/2)-C13/(1+C59)^(C12))/(1/C59-1/(C59*(1+C59)^(C12))))
	Operating	573.711	NPR/year	(=C24)
	Total	985.264	NPR/year	(=C60+C61)
Annual work produced	Number of passengers served	32.000	pax/year	(=C21*C22)
Cost effectiveness ratio (CER)		**30,79**	NPR/pax	(=C62/C63)

Table 39. Input values & CER calculation of the new shuttle van design

Existing open shuttle van - Investor's perspective - Input values				
Category	**Parameter**	**Value**	**Units**	**Comments**
General info	Year built (manufactured in India)	2019		Procured in 2019 by Lalitpur municipality
	Passenger capacity	8		
Propulsion	Battery type	Lithium ion		
	Battery size	5	kWh	Only 80% (=4 kWh) can be used before recharging
	Number of batteries	1		
Capital cost	Purchase price	3.500.000	NPR	2.800.000 NPR in 2019 prices; inflated by 25% (CPI- 2023/2019)
	- Manufacturing cost	1.925.000		Imported from India; breakdown is an estimate
	- Cost of drive train	1.250.000		Imported from India; breakdown is an estimate
	- Cost of battery	325.000		
	Expected useful life	12	years	Three cycles of 4 years (the expected life duration of the battery)
	Residual value	120.000	NPR	(=C14+C15)
	- Body	85.000	NPR	After 12 years
	- Battery	35.000	NPR	After 4 years (on the assumption of 7.000 NPR/kWh)
	Depreciation schedule	10%		Per year (Declining balance method)
Operational profile	Route	Lalitpur		Pulchwok to Mangalbazar
	Length of round trip	9	km	
	Round trips/day	5	trips/day	
	Total distance/day	45	km/day	(=C19*C18)
	Operating days/year	320	days/year	
	Passengers/day	40	pax	
	Chargings/day	1		Overnight charging
Yearly	Total operating cost	540.561	NPR/year	(=sum(C25:C30)+C34+C38+C50)
	* Licencing/renewal	5.000	NPR/year	
	* Route permit	2.000	NPR/year	
	* Vehicle road tax	0	NPR/year	Run by a municipality
	* Technical inspection	2.500		
	* Insurance	25.000	NPR/year	
	* Personnel cost	420.000	NPR/year	(=(C31+C32)*12+C33)
	- Basic monthly salary	35.000	NPR/month	
	- Monthly allowance	0	NPR/month	
	- Yearly bonus	0	NPR/year	
	* Electricity cost	9.761	NPR/year	Equivalent annual cost
	- Specific energy consumption	0,089	kWh/km	On the assumption that 45 km require 4 kWh
	- Battery efficiency	100,00	%	Drops by 3,5% every year
	- Electricity tariff	7	NPR/kWh	Special tariff for EVs
	* Maintenance cost	47.500	NPR/year	(=sum(C39:C49))
	- Tires	10.000	NPR/year	Once in 4 years.
	- Brake shoes	2.000	NPR/year	
	- Dent paint	15.000	NPR/year	60.000 NPR every 4 years
	- Suspension	10.000	NPR/year	
	- Wiring	4.500	NPR/year	
	- Headlights, tail lights	3.000	NPR/year	
	- Differential crown gear	0	NPR/year	
	- Fuses	500	NPR/year	
	- Display system	0	NPR/year	
	- Throttle pedal	1.500	NPR/year	
	- Motor servicing	1.000	NPR/year	
	* Other	28.800	NPR/year	(=sum(C51:C53))
	- Vehicle parking	0	NPR/year	Parking at own yard
	- Vehicle cleaning	28.800	NPR/year	(=2.400 NPR per month)
	- Other	0	NPR/year	
Yearly revenues	Total revenues	0	NPR/year	(=C19*C20*C52)
	Ticket fare/passenger	0	NPR/pax	Free of charge, used for disabled/elderly people
Income tax	Income tax rate	25%		
		Calculation of Cost Effectiveness Ratio (CER)		
Annualized cost	Discount rate	10%		
	Capital	556.985	NPR/year	(=(C8+(C11-C15)/(1+C59)^(C12/3)+(C11-C15)/(1+C59)^(2*C12/3)-C13/(1+C59)^(C12))/(1/C59-1/(C59*(1+C59)^(C12))))
	Operating	540.561	NPR/year	(=C24)
	Total	1.097.546	NPR/year	(=C60+C61)
Annual work produced	Number of passengers served	12.800	pax/year	(=C21*C22)
Cost effectiveness ratio (CER)		**85,75**	NPR/pax	(=C62/C63)

Table 40. Input values & CER calculation of the existing open-type shuttle van

As such, it was decided to proceed with a CER calculation. An annualised capital cost of 411,600 NPR is added to the annual operating costs to a total of 985,300 NPR. When assessed against a total of 32,000 passengers served over a year, a CER value of 30.79 NPR/passenger is derived (Table 39). For benchmarking purposes, the same exercise was repeated for the existing open-type van of Lalitpur municipality (Table 40). The higher capital cost of this vehicle combined with its very low utilisation (40 passengers per day on average) result in a CER value of 85.75 NPR/passenger. Judged against this mark, the new design corresponds to an impressive 64.09% reduction. However, as this result is sensitive to the capital costs and the number of passengers served, a sensitivity analysis is in order.

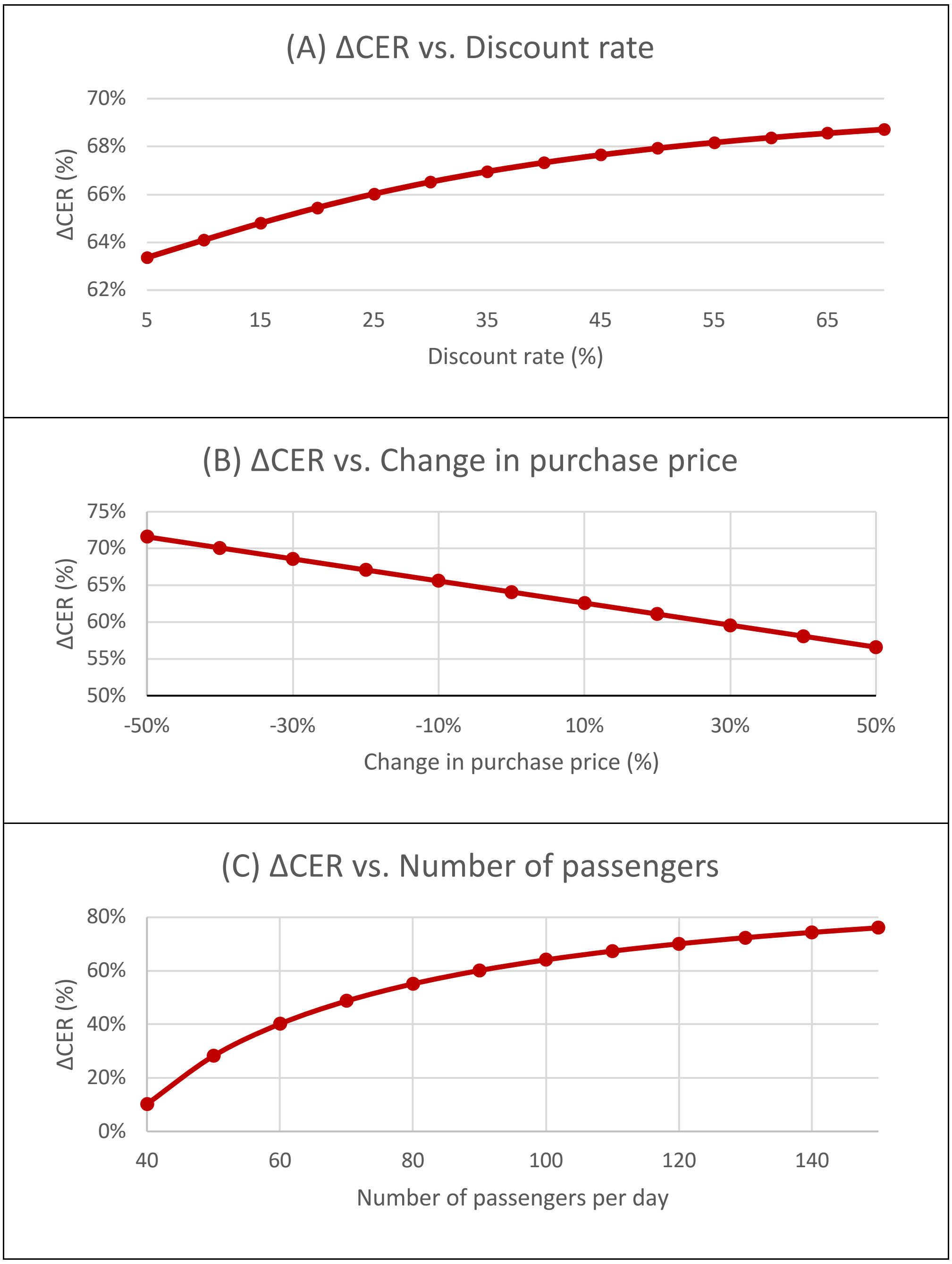


Figure 30. Newly designed e-shuttle van: Sensitivity analysis on ΔCER

Figure 30 shows that the CER improvement (ΔCER) is growing with the discount rate (due to the higher capital costs of the open van) but is not very sensitive to changes in this parameter. Nor changes in the purchase price of the new van constitute any major risk, as ΔCER remains above 56% even when the vehicle's price is increased by 50%. On the contrary, ΔCER appears very sensitive to the expected average number of passengers served. A reduction from the expected 100 daily passengers to the current figure (40 passengers per day) causes a dramatic drop of ΔCER from 64.09% to only 10.23%. Even then, however, the CER value of the new design remains below the mark set by the existing open van.

3.11.2. EFFECT ON EMISSIONS AND OTHER ENVIRONMENTAL ATTRIBUTES

Although the newly designed shuttle van was benchmarked against the existing open-type one for the financial performance, it will be compared to a diesel-run microbus when it comes to environmental attributes. The reasons are twofold: (i) there exists only one open-type e-shuttle van in operation transporting elderly/disabled people in Lalitpur municipality, and (ii) the widely used vehicle that is closest to the demo is a diesel-driven microbus used for taxi services. In such an operation, the vehicle is expected to cover 32,000 km/year (= 100 km/day x 320 days/year). According to Bajracharya & Bhattarai (2016), the fuel efficiency of a microbus in Nepal is 6.2 km/lt, based on which, the annual fuel consumption is estimated at 5,161 lt of diesel.

GHG emissions

Assuming a tank-to-wheel (TtW) CO2 factor of 2,423 gr/lt (Das, et al., 2022) and a well-to-tank (WtT) factor of 500 gr/lt (e-Mob default value), the above estimated amount of fuel corresponds to 15.09 tonnes of WtW CO2 emissions. Assuming that all electricity consumed by the e-shuttle van is derived from renewable resources, this is the amount saved annually per unit of e-shuttle van.

NOx emissions

Based on Sadavarte et al. (2019), the NOx emissions factor for microbuses in the Kathmandu valley is estimated at 13.71 gr/lt (15.94 gr/kg of fuel). The application of this factor on the annual fuel consumption estimated above results in a figure of 70.75 kg of NOx emissions abated annually per unit of shuttle van.

PM2.5 emissions

Similarly, the PM2.5 emissions factor for this type of fuel and vehicle is 4.69 gr/lt (Das et al., 2022). The mass of abated PM2.5 emissions annually per unit of e-shuttle van then becomes 24.19 kg.

Noise

At the time of drafting this document, the noise measurements of the newly designed shuttle van had not been finalised pending completion of the demo vehicle.

4 ASSESSMENT OF THE SCALED-UP PROJECT

4.1. BASELINE SCENARIO

As explained in Volume 1 (Section 1.2), 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 CO2, NOx and PM2.5 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[13], 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 (CO2, NOx, PM2.5) over the entire time horizon, alongside outlining the required infrastructure and its associated costs.

As seen in Figure 31, 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.

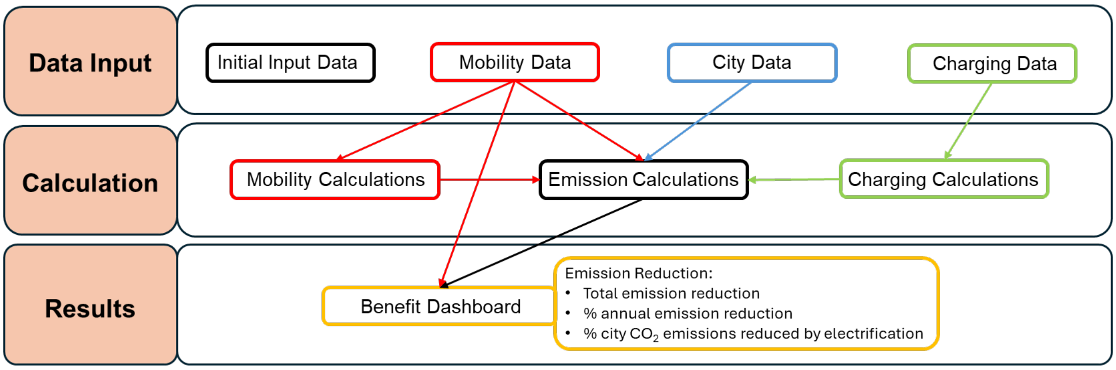


Figure 31. FMC components and functionality

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

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 (the appropriate term for the converted bus of Section 3.4), microbuses (corresponding to the shuttle van of Section 3.11), 3-wheelers (for the demo vehicles of Sections 3.5 and 3.7), and pick-up trucks (for the remaining demo vehicles). The total number of vehicles for 2022, as shown in Table 41, 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[14] estimates about 1,000 non-diesel vehicles, out of which about 700 are Safa Tempos.

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%).

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% for the pick-up trucks. 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. The mileage, fuel efficiency and emission factors of Table 41 are in line with the figures used for the respective financial assessments of Section 3.

Based on these inputs, the baseline scenario CO2 (WtW), NOx and PM2.5 emissions, as computed by FMC, are depicted in Figure 32 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

14 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

Table 41. 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									

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 47.

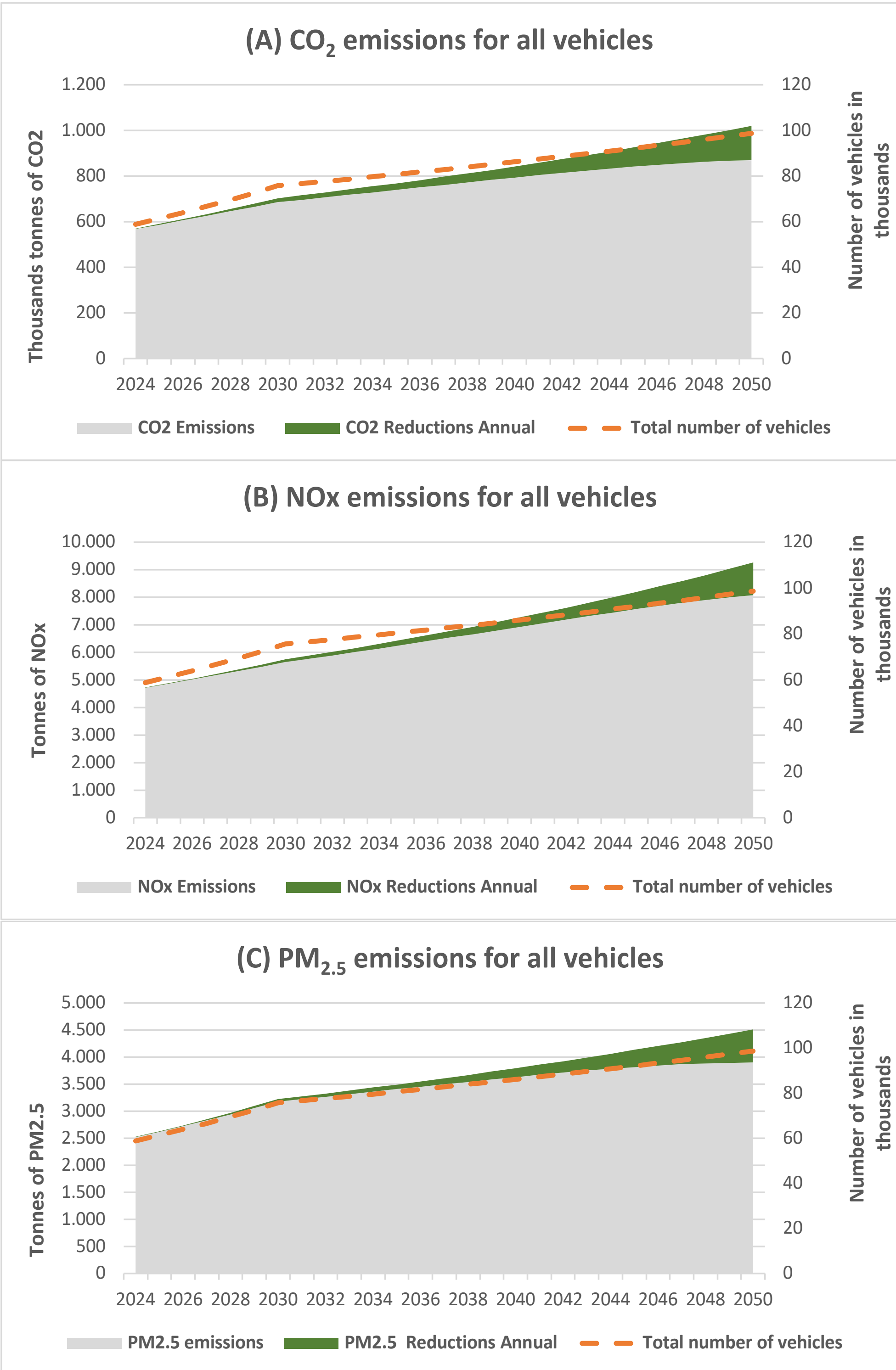


Figure 32. Baseline scenario emissions

4.2. KPIS FOR ASSESSING THE SCALED-UP PROJECT

All KPIs of Figure 4 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 of Table 7. 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 the following headings.

4.2.1. EFFECT ON JOBS

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 43, where also the net effect per unit of manufactured vehicle is presented.

4.2.2. EFFECT ON TECHNICAL SKILLS

As stated in Vol.1 (Appendix B6.3), this KPI is defined based on the net positions of technically skilled employees required for the manufacturing and maintenance of EVs. The specialties of concern are: (i) EV technicians, (ii) EV design engineers, and (iii) IT analysts or other Industry 4.0 experts. These positions are transformed into EV technician equivalent ones, through the corresponding mean salaries earned in Nepal, as provided in: https://www.paylab.com/salary-report?lang=en. Table 42 summarises the salary information (in US$) obtained through this link on 23/1/2024 and calculates the corresponding conversion factors.

	10% earn less than	10% earn more than	Mean value	Conversion factor
Auto electrician	US$ 140	US$ 294	US$ 217.00	1:1
Auto design engineer	US$ 119	US$ 394	US$ 256.50	1:1.18
IT analyst	US$ 161	US$ 548	US$ 354.50	1:1.63

Table 42. Conversion factors for calculating the EV technician equivalent positions (as of 23/1/2024)

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.					

Table 43. Effect on job creation

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.												

Table 44. Effect on technical skills

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 44. 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.

4.3. SCALED-UP PROJECT DESIGN

The baseline scenario of Section 4.1 and the KPIs on employment of Section 4.2 complete the basic input for designing the scaled-up project. Before presenting some methodological issues concerning the optimisation process itself in the next heading, 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.[15] 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 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.

4.3.1. METHODOLOGICAL ASPECTS

As mentioned in Section 2.1.1 (Vol.1), the optimisation objective function is of the

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

following form:

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

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 xj 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.

4.3.2. OPTIMISATION RESULTS

Table 45 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.

The optimisation results appear in Table 46. With an overall rating of 3.29656, a fleet composed of 25 buses, 20 waste collectors and 30 shuttle vans is the best performing

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	-4,00	-15,09
D1.	Effect on NOx emissions (kg/year/unit)	0,028315	0,035140	-201,30	-18,35	-70,75
D2.	Effect on PM2.5 emissions (kg/year/unit)	0,035386	0,043915	-52,00	-25,23	-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	4,5	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					

Table 45. Input for the optimisation model

	Simulated annealing	Evolutionary algorithm	Grey wolf optimiser
Best star rating found	3.29656	3.29656	3.29656
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	41 /100	7 / 100	95 / 100
Efficiency: Average duration of computing time	0.22 seconds	1.67 seconds	0.09 seconds

Table 46. Optimisation results (Scenario A)

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 3.29656, achieved with a configuration of 25 buses, 20 waste collectors, and 30 shuttle vans.

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%

Table 47. Estimated effect of the scaled-up project on emissions (Scenario A)

The effect of the scaled-up project on emissions is obtained by channelling the optimisation results into the FMC. Table 47 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 33. It is interesting to observe that emissions now peak during the period and start dropping towards the end of the 2040s.

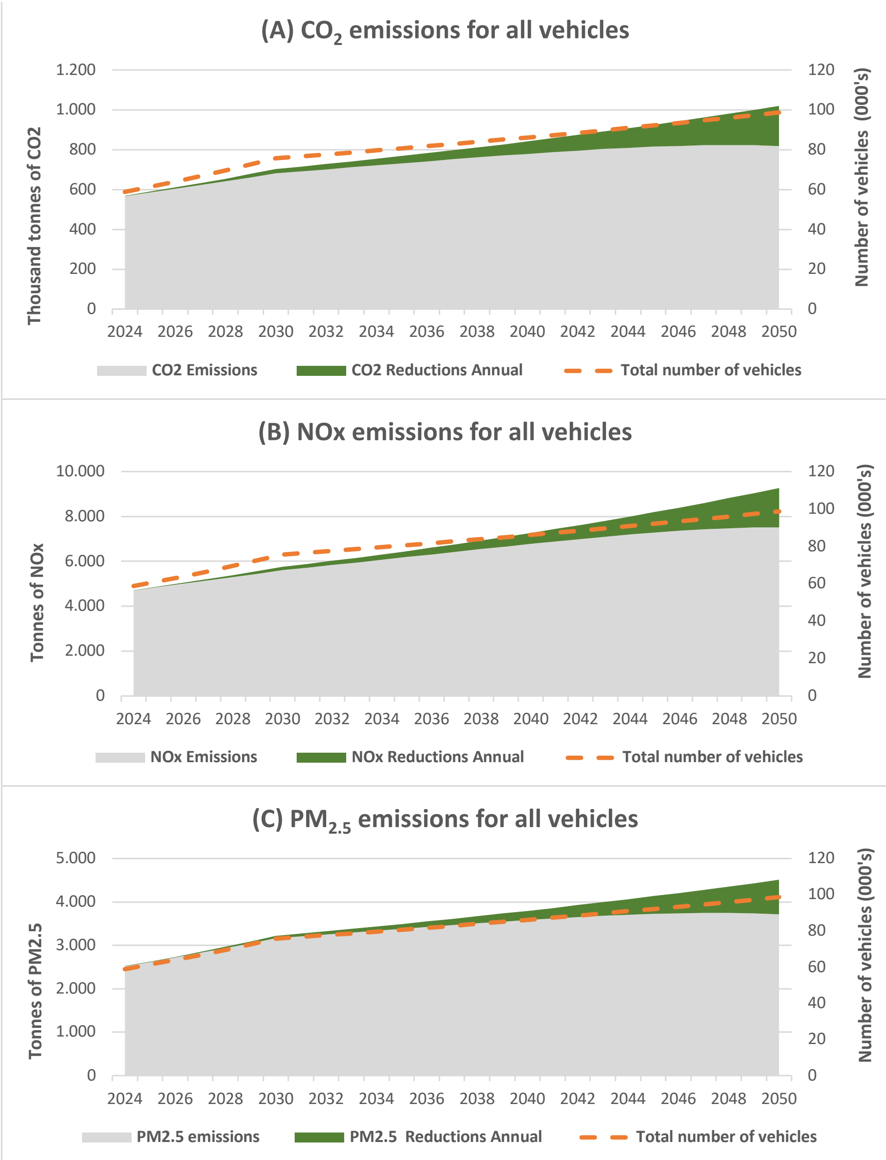


Figure 33. Effect of the scaled-up project on emissions (Scenario A)

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 48).

For both scenarios, Tables 46 and 48 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:

- Processor: AMD Ryzen 5 PRO 5650U with Radeon Graphics 2.30 GHz
- Installed RAM: 16,0 GB (14.8 GB usable)
- Device ID: EC7911AB-ECFA-43A5-B4F1-1134DCD53EB9
- Product ID: 00330-80000-00000-AA322
- System type: 64-bit operating system, x6

	Simulated annealing	**Evolutionary algorithm**	**Grey wolf optimiser**
Best star rating found	3.25504	3.25504	3.25504
Best fleet found	[bus, waste] [40, 10]	[bus, waste, van] [25, 20, 30]	[bus, waste, van] [25, 20, 30]
Effectiveness: Frequency of occurrence of best star rating	55 /100	97 / 100	100 / 100
Efficiency: Average duration of computing time	0.11 seconds	1.16 seconds	0.08 seconds

Table 48. Optimisation results (Scenario B)

4.3.3. 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 200.000 (lump sum)
- in e3Ws & converted pick-up trucks
- 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

5 DISCUSSION

This section discusses the work performed in relation to the impact assessment of the Kathmandu part of SOLUTIONSplus. The discussion is structured along two central themes: the assessment of the Kathmandu demo activities, and the assessment methodology itself.

5.1. ASSESSMENT OF THE KATHMANDU DEMO ACTIVITIES

Demo design & user needs analysis

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

Stakeholder priorities

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

Demo vehicles

Table 49 summarises the findings of the demo assessment. The financial results are promising, with all vehicles achieving top score, except for the converted bus and the waste collector (with a score of 3 and 4 respectively). For the six revenue-earning components, IRR ranges from 14,86% (converted bus) to 87,53% (new e3W design cargo). Both non-revenue-earning components exhibit significant reductions in the CER values, although care should be taken to verify these results in practice, as they are very sensitive to the actual transport work performed (volume of waste collected and passengers carried respectively).

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

All demo vehicles demonstrate significant emission reduction potential, except for the passenger 3Ws, intended to replace the aging electric Safa Tempo fleet. However, the battery recycling infrastructure of the country needs to be addressed to enhance the environmental advantages of e-mobility.

Furthermore, and to deploy EVs effectively, the city needs proper planning for charging infrastructure, supporting regulatory framework and policies for manufacturing (e.g., technical standards, licensing, etc.), as well as awareness raising among investors and operators/drivers.

Scaled-up project

Given that all five of the demo vehicles that fall under the private sector (the four e3Ws and the converted pick-up truck) exhibit healthy financial returns, no subsidies are required for their promotion. As such, with regard to these vehicles, the scaled-up project includes only support activities (monitoring the prototypes' operation to verify their technical and financial viability, informing commercial banks about potential targeted loan schemes, and undertaking awareness campaigns targeting potential investors and operators). An optimisation exercise has been undertaken concerning the remaining three vehicles. For a budget of € 2 million, a fleet of 25 buses, 20

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

Table 49. Summary table of all demo vehicles

waste collectors and 30 shuttle vans exhibits the best performance in meeting the stakeholder priorities. If the Lalitpur municipality wishes to exclude the shuttle vans, which are targeted to the tourist industry, the optimal fleet becomes 40 buses and 10 waste collectors.

Prefeasibility of a MaaS application

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

5.2. THE ASSESSMENT METHODOLOGY

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

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

e. At the first stakeholder workshop, the following three KPIs were considered irrelevant for the Kathmandu demo and excluded from the value function development:
- Effect on accessibility – passengers (E1)
- Effect on well-being through active travelling (E11)
- Effect on drivability as perceived by end users (E15)

f. Five more KPIs turned out to be irrelevant after obtaining information from the end users, drivers, and experts:
- Effect on accessibility – freight (E2)
- Effect on affordability (E3)
- Effect on travel time – passengers (E4)
- Effect on travel time – freight (E5)
- Effect on transhipment quality (E19)

g. Another two KPIs were dropped due to difficulties in obtaining the necessary data:
- Effect on budget (F1)
- Effect on other imports (F3)

h. One more KPI was finally dropped due to a great deal of overlap with the emission-related indicators, when viewed outside the external trade context:
- Effect on fossil fuel imports (F2)

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

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

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

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

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

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

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

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

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

REFERENCES

1. 1ADB, 2013. Country Partnership Strategy 2013-2017: Sector Assessment (Summary) – Transport and Information and Communication Technology. An Asian Development Bank report, https://www.adb.org/sites/default/files/linked-documents/cps-nep-2013-2017-ssa-02.pdf (Accessed 5/12/2019).
2. ARAI, 2007. Emission factor development for Indian vehicles as a part of ambient air quality monitoring and emission source apportionment studies. Draft report of the Automotive Research Association of India in the framework of the Air Quality Monitoring Project-Indian Clean Air Programme (ICAP).
3. Bajracharya, I. and Bhattarai, N., 2016. Road Transportation Energy Demand and Environmental Emission: A Case of Kathmandu Valley. Hydro Nepal: Journal of Water, Energy and Environment, Vol.18, p.30-40.
4. CEN, 2020. Fuel Economy Labelling of LDVs in Nepal. Clean Energy Nepal, https://www.cen.org.np/uploaded/Fuel%20Economy%20Labelling%20of%20LDVs%20in%20Nepal_Factsheet%20Revised.pdf (Accessed 18/2/2020).
5. CSE, 2012. Kathmandu can manage its urban transportation and become pollution-free if it builds on its strength – its emission-free non-motorised transport: says CSE. Centre for Science and Environment, https://www.cseindia.org/kathmandu-can-manage-its-urban-transportation-and-become-pollution-free-if-it-builds-on-its-strengths-its-emission-free-non-motorised-transport-says-cse-4395 (Accessed 16/11/2020).
6. Das, B., Bhave, P.V., Puppala, S.P., Adhikari, S., Sainju, S., Mool, E., Byanju, R.M. 2022. Emission factors and emission inventory of diesel vehicles in Nepal. Science of the Total Environment, Volume 812, 152539.
7. Devkota, S., Pokhrel, R., Rayamajhi, B., Uprety, B. 2021. Design and cost estimation of a CO2 capture plant from cement flue gas for urea production in Nepal. International Journal of Greenhouse Gas Control, Volume 111, 103484.
8. DoTM, 2019. Number of vehicle registrations. Ministry of Physical Infrastructure and Transport, Department of Transport Management, Kathmandu, Nepal, https://www.dotm.gov.np/Files/NoticePDF/zonalwise0730742020-01-17_04-38-58-080.pdf (Accessed 15/12/2020).
9. Gautam, S., 2020. Comparative Study of Lead Acid and Lithium Ion Battery Used in Safa Tempo in Kathmandu Valley. MSc thesis submitted to the Department of Mechanical Engineering, Tribhuvan University, Lalitpur, Nepal.
10. GGGI, 2018a. National Action Plan for Electric Mobility: Accelerating Implementation of Nepal's Nationally Determined Contribution. A Global Green Growth Institute report, Seoul, Republic of Korea.

11. GGGI, 2018b. Deploying Electric Buses in the Kathmandu Valley. A Pre-Feasibility Study. A Global Green Growth Institute report, Seoul, Republic of Korea.
12. GoN, 2020. Second Nationally Determined Contribution (NDC). A Government of Nepal document, Kathmandu, Nepal.
13. .IBRD, 2024. World Development Indicators, https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?locations=NP (Accessed 25/02/2024).
14. IBRD, 2019. Nepal infrastructure sector assessment: Private sector solutions for sustainable infrastructure development. International Bank for Reconstruction and Development / The World Bank, Washington, DC, USA.
15. JICA, 2012. Data Collection Survey on Traffic Improvement in Kathmandu Valley. Final report, Japan International Cooperation Agency.
16. Karali, N., Abhyankar, N., Sharpe, B., and Bandivadekar, A., 2019. Improving fuel efficiency for heavy-duty vehicles of 3.5–12 tonnes in India: Benefits, costs, and environmental impacts. A Lawrence Berkeley National Laboratory report, https://escholarship.org/uc/item/3sh394nv
17. MoFE, 2021. Nepal's Third National Communication to the United Nations Framework Convention on Climate Change. Ministry of Forest and Environment, Government of Nepal (p. 3).
18. NEA, 2022. Nepal Electricity Authority: A Year in Review – Fiscal Year 2021/2022, Kathmandu, Nepal.
19. OECD, 2020. Non-exhaust Particulate Emissions from Road Transport: An Ignored Environmental Policy Challenge. An Organisation for Economic Cooperation and Development report, https://www.oecd-ilibrary.org/sites/4a4dc6ca-en/index.html?itemId=/content/publication/4a4dc6ca-en (Accessed 20/2/2024).
20. Ortving, A. and Brodthagen, M., 2022. An Analysis of Kathmandu's Public Transport System and Viable Improvements through MAAS IT solutions: A Pre-Feasibility Study. Bachelor's thesis submitted at the Technical University of Denmark.
21. Poudel, K.L., Nepal, A.P., Dhungana, B., Sugimoto, Y., Yamamoto, N., Nishiwaki, A., 2009. Capital Budgeting Analysis of Organic Coffee Production in Gulmi District of Nepal. Paper prepared for presentation at the International Association of Agricultural Economists Conference, Beijing, China, August 16-22, 2009.
22. Ross, J.C., Staiano, M.A., 2007. A comparison of green and conventional diesel bus noise levels. Institute of Noise Control Engineering of the USA - 22nd National Conference on Noise Control Engineering, Volume 1, pp. 569-576.
23. Sadavarte, P., Rupakheti, M., Bhave, P.V., Shakya, K., Lawrence, M.G., 2019. Nepal Emission Inventory - Part I: Technologies and combustion sources (NEEMI-Tech) for 2001-2016 (Supplement of), Atmospheric Chemistry and Physics Discussions, pp. 1-33.

24. Saud, B. and Paudel, G., 2018. The Threat of Ambient Air Pollution in Kathmandu, Nepal, Journal of Environmental and Public Health, Volume 2018.
25. Shrestha, S.R., Oanh, N.T.K., Xu, Q., Rupakheti, M., Lawrence, M.G., 2013. Analysis of the vehicle fleet in the Kathmandu Valley for estimation of environment and climate co-benefits of technology intrusions. Atmos. Environ., 81, 579–590, https://doi.org/10.1016/j.atmosenv.2013.09.050
26. Sochor, J., Arby, H., Karlsson, I.C.M-A., Sarasini, S., 2018. A topological approach to Mobility as a Service: A proposed tool for understanding requirements and effects, and for aiding the integration of societal goals. Research in Transportation Business and Management, Volume 27.
27. Timsina, N.P., Shrestha, A., Poudel, D.P., Upadhyaya, R., 2020. Trend of urban growth in Nepal with a focus in Kathmandu Valley: A review of processes and drivers of change. Tomorrow's Cities Working Paper 001, https://www.tomorrowscities.org/sites/default/%20files/resources/2020-11/Tomorrow%27s%20Cities%20Working%20Paper%20%231.pdf (Accessed 15/2/2021).