Comparative Analysis of City-specific Light Freight EV Applications in Asia, Africa and Latin America

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Abstract. The paper compares selected financial, environmental and social aspects pertaining to eight light freight electric vehicles that the SOLUTIONplus project designed and tested in developing countries. They range from e-3W & 4W in Kathmandu, e-quadricycles in Pasig, e-cargo bikes in Quito and Montevideo, and e-bikes in Dar Es Salaam. All prototypes are co-developed by local manufacturers and aim to replace traditional vehicles powered by fossil fuels, while considering local conditions and priorities. They have proven a good solution for last-mile urban deliveries, due to their flexibility, small dimensions and low investment requirements. All vehicles tested exhibit a healthy return on investment. However, the lighter vehicles such as the e-bikes and e-cargo bikes appear very sensitive to demand forecasts requiring a well-functioning distribution network and integration services leading towards collaborative business models. Conversions of existing vehicles are generally profitable albeit at lower return rates. In general, the old fossil-fuel-driven solutions are also profitable depriving operators of running vehicles from sufficient motivation to convert. As such, conversions at scale can be expected only at the end of the useful lives of existing vehicles. Cities need proper infrastructure planning, supporting regulations and policies for manufacturing, and awareness raising among drivers.

Keywords: e-Mobility, Urban Freight, Developing Countries.

1 Introduction

Despite its vital role in meeting the daily needs of more than 55% of the global population that lives in cities today [1], urban freight transportation is associated with significant externalities, such as adding to the traffic congestion, conflicting with other road users (often due to limited parking and (un-) loading facilities) and significant air quality, noise and road safety issues [2, 3]. The frequent land use conflicts and inadequate regulation, maintenance and management of the vehicle stock and road infrastructure in developing countries aggravate these problems. Light-duty electric freight vehicles (LEFVs) offer a potential solution to these challenges, particularly those concerning the environmental implications of last-mile urban delivery services [4, 5].

The EU-funded SOLUTIONSplus project [6], which aims at kick starting urban e-mobility in developing countries, has included eight LEFV demonstration activities in Asia, Africa and Latin America. All these prototypes, which consider local conditions and priorities and are co-developed by local manufacturers, will be examined here:

- *Remodeled Safa tempo for cargo (Kathmandu)*. Safa tempos are electric 3Ws built in late 1990s for passenger transport. A remodeled Safa tempo, already in cargo operations, demonstrates the possibility of expanding the vehicle's utility to freight transport while replacing a conventional ICE petrol-powered Tata Ace pickup truck.
- *New e-3W cargo design (Kathmandu)*. Designed as an alternative to the petrol-powered Tata Ace pickup truck, provides access to the secondary and tertiary narrow streets of the city in a carbon-free manner.
- *New e-4W design for waste collection (Kathmandu)*. Currently, Lalitpur Municipality uses petrol-powered 3Ws with open trunks to collect waste, subsequently transferring it to larger containers for disposal. The new e-4W prototype is a closed design that will offer improved hygiene and environment-friendly services.
- *Converted pickup truck (Kathmandu)*. Aims to replace the widely used petrol-powered Tata Ace pickup truck, while enhancing the efficiency of cargo services.
- *E-quadricycle (Pasig)*. Powered by high quality second-life batteries from Europe, this novel shared multi-purpose EV aims to replace existing ICE-powered all purpose vehicles.
- *E-bike (Dar es Salaam)*. Pedal-assist electric bicycles aimed at replacing ICE-powered motorcycles for the delivery of medical supplies to a local hospital among other uses.
- *E-cargo bike (Quito)*. Aligned with the vision of a pedestrian-friendly low-emission zone in the historic center of Quito, e-cargo bikes were tested as replacements for motorcycles (courier services), cars (restaurant) and manual carts (recycling associations and stevedores from a local market).
- *E-cargo bike (Montevideo)*. E-cargo bikes of two different configurations (a 2W and a 3W option) were tested through a platform (mobile app) as replacements of common bicycles without pedal assistance.

The project has developed an impact assessment methodology that combines the classic financial cost-benefit analysis (CBA) with multi-criteria decision analysis (MCDA) techniques to investigate potential effects on all sustainability pillars.

The 34 Level-3 key performance indicators (KPIs) of the project's assessment methodology form 20 Level-2 families and 6 Level-1 categories. The weights assigned by the stakeholders to the Level-1 KPIs in the five demo cities of interest in this paper appear in Table 1. They resulted from a 2-round Delphi method application involving 10-20 knowledgeable individuals from all stakeholder groups in each city, thus, reflecting the corresponding stakeholder priorities.

On average, project finances hold the top position with a share of 18.87%. This is more profound in Kathmandu, where the financial performance of the project attracts the highest stakeholder interest among all demo cities (23.44%). Hence, the financial assessment of the project LEFVs will be given the highest attention in this analysis.

Table 1. KPI weights for the demo cities (stakeholders' input)

	Kath.	Pasig	Dar	Quito	Mont.	*Avg.*
Project finances	23.44	17.75	16.00	18.35	18.82	*18.87*
Institutional framework	17.65	15.09	14.30	15.21	16.43	*15.74*
GHG emissions	13.19	17.25	16.20	16.65	16.40	*15.94*
Environment	15.46	19.88	16.90	18.63	16.55	*17.49*
Society	13.81	14.15	18.30	17.32	18.03	*16.32*
Wider economy	16.44	15.87	18.30	13.84	13.77	*15.64*
Total	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*

Preliminary results of the project focusing on the financial assessment of the solutions examined are presented in the next section. Section 3 discusses specific environmental and social attributes of interest to the local communities. Identified conditions enabling the vehicles' effective operation are discussed in Section 4, which also concludes.

2 Financial analysis

The financial performance of the project vehicles is assessed either through the Net Present Value (NPV), Internal Rate of Return (IRR), and payback period for revenue-earning operations, or the Cost Effectiveness Ratio (CER) otherwise. Due to the size limitations of this paper, it was decided to restrict the analysis to IRR. Furthermore, and in order to exclude tax-related effects, the discussion is based on before-tax returns. The expected IRRs for six project vehicles are shown in Fig.1. They denote returns on investment associated with the acquisition of the demo vehicle exclusively through own funds, and its operation according to an operational profile typical for the vehicle type examined in the corresponding demo city. Two more vehicles will be assessed through the CER approach.

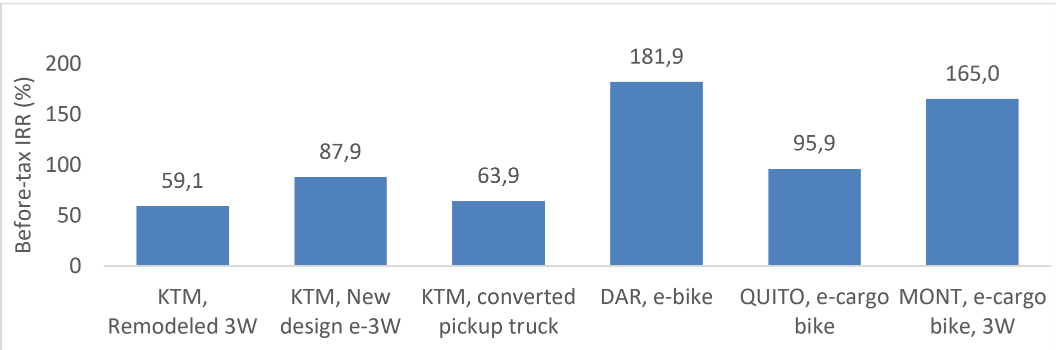

Fig. 1. Before-tax IRR (%) – Investor's perspective

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

The Dar e-bike costs about € 770 ($ 820) and its Fig.1 performance assumes an average of 9.7 daily deliveries, which is the current production of an ICE motorcycle used by the targeted hospital. This can only be achieved if the customer base is expanded, a digital order/fleet management system is introduced, and the e-bikes are equipped with a second battery to be swapped during the day. In the absence of this second battery, only 6 daily deliveries are possible, and the IRR drops dramatically to -1.1%.

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

With a € 2,630 ($2,800) investment, the Quito Long John e-cargo bike generates a return of 95.9% when performing 8 short trips within the historic center of the city. Other configurations tested in Quito proved much more cost effective than a petrol-run car serving a local restaurant, and also more effective than manual carts used for recycling waste due to significant increases in productivity.

The Kathmandu vehicles are larger. With a 10kWh LiFePO4 battery, the € 9,920 newly designed 3W offers a return of 87.9% when performing 3.5 trips/day on average. For comparison purposes, a new petrol-driven Tata Ace pickup truck (the most popular alternative), costing € 13,900, generates a return of 44.9% under identical operations.

A cargo 3W was also produced through remodeling an existing ‘safa tempo.’ Safa tempos are electric passenger 3Ws that were constructed in late 1990’s and are approaching the end of their useful life. In addition to replacing the passenger cabin with a cargo platform, the remodeling included replacing the old lead-acid battery with a li-ion 23 kWh set. Over the useful life of 6 years, the required investment of € 13.720 (NPR 1,950,000) is expected to produce a return of 59.1%. Seen from a safa tempo operator’s viewpoint, however, the picture is different. Until the expiration of its license, an existing safa tempo is expected to make a pre-tax profit of NPR 1.280.000. This constitutes earnings foregone for the operator who decides to remodel their vehicle. After accounting for this additional cost, the IRR of a safa tempo remodeling drops to 41.3%, which is still quite attractive.

The conversion of a 15-year old petrol-driven Tata Ace pickup truck, worth about € 3,170, to electric was also tested in Kathmandu. The € 13,560 total investment leads to an IRR of 63.9%. However, during the remaining 6 years of its life, this vehicle is expected to produce a NPV of about NPR 3.5 million (at a discount rate of 10%). After considering this foregone profit, the pickup operator is expected to make a further profit of NPR 737,000 before-tax on the conversion, equivalent to a 14.9% return.

In relation to non-revenue-earning operations, the design of the new e-4W waste collector in Kathmandu has been optimized to achieve 495 NPR/cu.m. of waste collected, 13.5% lower than the CER of the petrol-powered 3W currently used by the Lalitpur municipality. At 70.30 PHP/ton-km, the cost savings achieved by the Pasig e-quad against the existing ICE-powered vehicles that move primarily medicines to/from public hospitals, clinics, and local health centers on behalf of the City Health Department are even more impressive (43.8%).

3 Environmental and social attributes

In Kathmandu, no major environmental impact is expected from the remodeled 3W, as it replaces an older electric vehicle. This is not the case, however, for the newly designed 3W and the converted truck, both of which will typically replace a petrol-driven Tata Ace pickup. The yearly CO_2 emissions of this vehicle for the same mileage are estimated at 5.8 tonnes on a well-to-wheel basis. The corresponding NOx and $PM_{2.5}$ emissions (on a tank-to-wheel basis) are 24.9 and 36.9 kg/year respectively. The annual emissions of the petrol-powered 3W waste collector are estimated at 2.8 tonnes of CO_2, 12.1 kg of NOx and 18.0 kg of $PM_{2.5}$. Given that almost all electricity production in Nepal is hydro-based, it can be safely assumed that the above figures constitute the emissions abated by each unit of the two vehicles under examination. In relation to societal impacts, figures have been compiled only for the remodeled safa tempo, the prototype of which has already been tested. The drivers interviewed found significant improvement in comparison to an ICE-run pickup in terms of noise and drivability, and slight improvement in accessibility, comfort and safety. The old solution was found easier to charge/refuel though. No impact on road safety was foreseen by the experts interviewed. In relation to institutional issues, the lack of technical standards for electric vehicles and the frequent rotation of public servants in Nepal hinder the promotion of e-mobility in the country.

In Pasig, the commercial ICE vehicle to be replaced by the project e-quad emits over the same mileage 0.5 tonnes of CO_2 (WtW), 1.0 kg of NOx (TtW), and less than 0.1 kg of $PM_{2.5}$ (TtW) per year. The e-quad was favored for its ease of driving and compatibility for first-/last-mile operations due to its capability to travel narrow roads. However, the e-quad scored unfavorably in terms of suitability of adverse weather conditions (battery is prone to get wet during flooding), travel comfort (lack of air-conditioning), security (parts can easily be stolen), and continuity of journey chains. In relation to institutional issues, uncertainties in alignment of the regulatory framework at the national and city levels (e.g., regarding the extent to which EV types are allowed on certain roads) hinder the promotion of e-mobility in the demo city.

The e-cargo bikes of Montevideo are tested against traditional bicycles, leading to a higher carbon footprint that depends on the carbon intensity of the grid electricity. In general, however, their carbon emissions are much lower than those of an ICE van (23.6 vs. 389.0 gCO_2e/km), something that applies on NOx emissions, too (0.066 vs. 1.794 gNO_xe/km) [7]. In Quito and Dar es Salaam, the project LEFVs aim to replace gasoline motorcycles, which emit 59.9 gCO_2, 0.26 gNOx and 0.1 $gPM_{2.5}$ per km [8]. The corresponding emissions of the e-bikes depend on the source of electricity generation but can be much lower, ranging from 1:5 for CO_2 to 1:40 for $PM_{2.5}$ emissions [8].

4 Conclusions

LEFVs prove a popular solution for last-mile urban deliveries, particularly in developing countries such as those of the SOLUTIONSplus project, due to their flexibility, small dimensions and low investment requirements. All vehicles tested exhibit a healthy return on investment, meaning that no financial support is required for their promotion. However, the lighter vehicles such as the e-bikes of Dar es Salaam and the e-cargo bikes of the Latin American cities appear very sensitive to demand forecasts. A well-functioning distribution network (probably supported by a digital management scheme) and integration services (exploiting the consolidation possibilities of e-cargo bikes) are necessary for the efficient operation of LEFVs, leading towards collaborative business models according to the 'broader EV uptake' approach [4]. Furthermore and in order to deploy them effectively, cities need proper planning for infrastructure (both for accommodating the rather bulky e-cargo bikes and for charging), supporting regulatory framework and policies for manufacturing (e.g., technical standards, licensing, etc.), and awareness raising among drivers.

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

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