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This is an interim draft that has been completed prior to the implementation of demonstrations in cities and was finalised based on individual city reports (status as of 31 March 2021)

Working Paper: Impact Assessment - KIGALI

Background and context

6.1.1. Geography and the social/urban context
Kigali City (Figure 6.1), the capital of Rwanda, is situated almost in the centre of the country. Its geographical position is at latitude 1º 57'S, and longitude 30º 04'E. Kigali is situated in the natural region called Bwanacyambwe within the Nyabugogo river basin's proximity, between Mount Kigali (1852 m high) and Mount Jali. The city is built on interlocking hills, which progressively converge and are separated by large valleys giving them oval shapes. Originally the city occupied the hills of Nyarugenge and Nyamirambo, which covered about 200 hectares at the time of independence (Niyonsenga 2012, City of Kigali 2013). The city is ringed towards the north and west by higher hills. The highest of these is Mt. Kigali, with an elevation of 1 850 metres ASL.

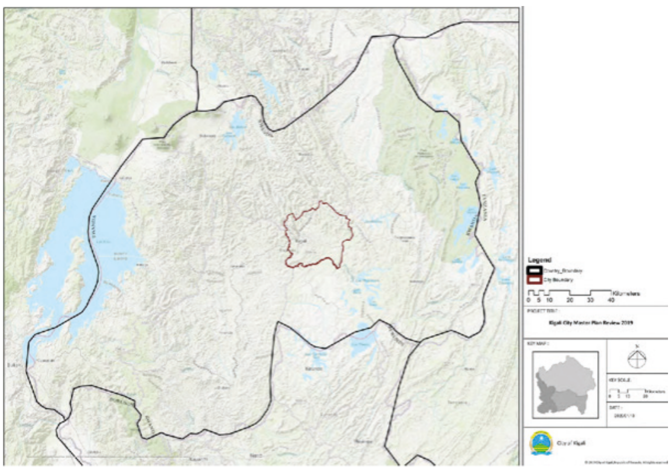


Figure 6-1: The city of Kigali 2018
(City of Kigali 2020)

The southern reaches of the district is defined by the Nyabarongo River, which forms the marshes of Kigali. Within Rwanda, Kigali province shares borders with three other provinces (East, North and South); the West province forms Rwanda's borders with Lake Kivu to the west and the North and South provinces to the east(City of Kigali 2020).

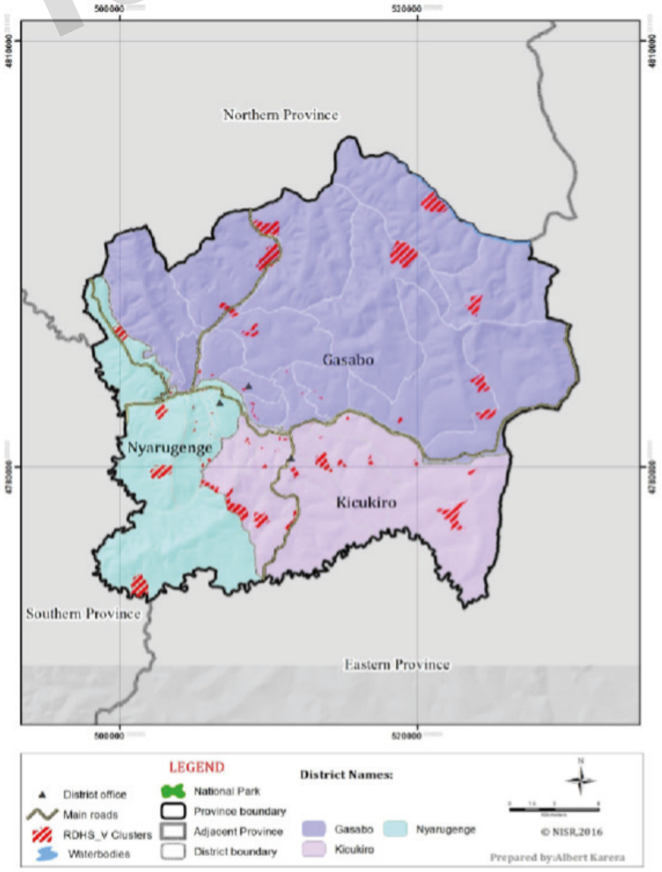


Figure 6-2: Kigali Districts
(Source:RDHS district chart handbook city of Kigali)

The city stretches from the centre to include, towards the east, the hills of Kacyiru, Kimihurura, Mburabuturo, Nyarutarama, Remera and Kanombe, towards the south over the slope of mount Nyarutarama, towards the west over the slope of mount Kigali, on slopes of Kabusunzu hills, Kimisagara and Butamwaowards, and towards the north over the slopes of mount Jali and hills of Gisozi, Gaculiro, Kagugu and Kibagabaga (SPEA Engineering 2019). The city of Kigali has an area of 730 sq. km, of which 33.2% is developable, and 17% is built upon.

As shown in figure 6.2, the city of Kigali has three districts: Nyarugenge, Gasabo and Kicukiro. The city has 35 sectors, 10 sectors in Nyarugenge, 15 in Gasabo and 10 in Kicukiro. Nyarugenge is 134 sq. km and has a population of around 0.35 million; Gasabo is 430 sq. km and has a population of around 0.6 million, and Kicukiro is 167 sq. km area and has a population of 0.35 million (SPEA Engineering 2019).

As the country's commercial and administrative hub, Kigali is rapidly urbanizing due to a growing population and increasing economic activities (World Population Review, 2019). In Rwanda in 1991, only 6% of its population lived in urban areas, which changed to 12 % in 1999 and 17% in 2018. Consequently, the estimated city population in 2013 was around 1.3 million (City of Kigali 2013), which was estimated to be 1.5 million in 2018 (Sudmant, Kalisa et al. 2019). The 2013 city master plan projects the city population to be around 3.8 million by the year 2050. The 2018 population density (people per hectare) is shown in Fig.6.3. As one would expect the areas with the highest population density is in the centre of Kigali. The average population density for Kigali is approximately 25 people per hectare.

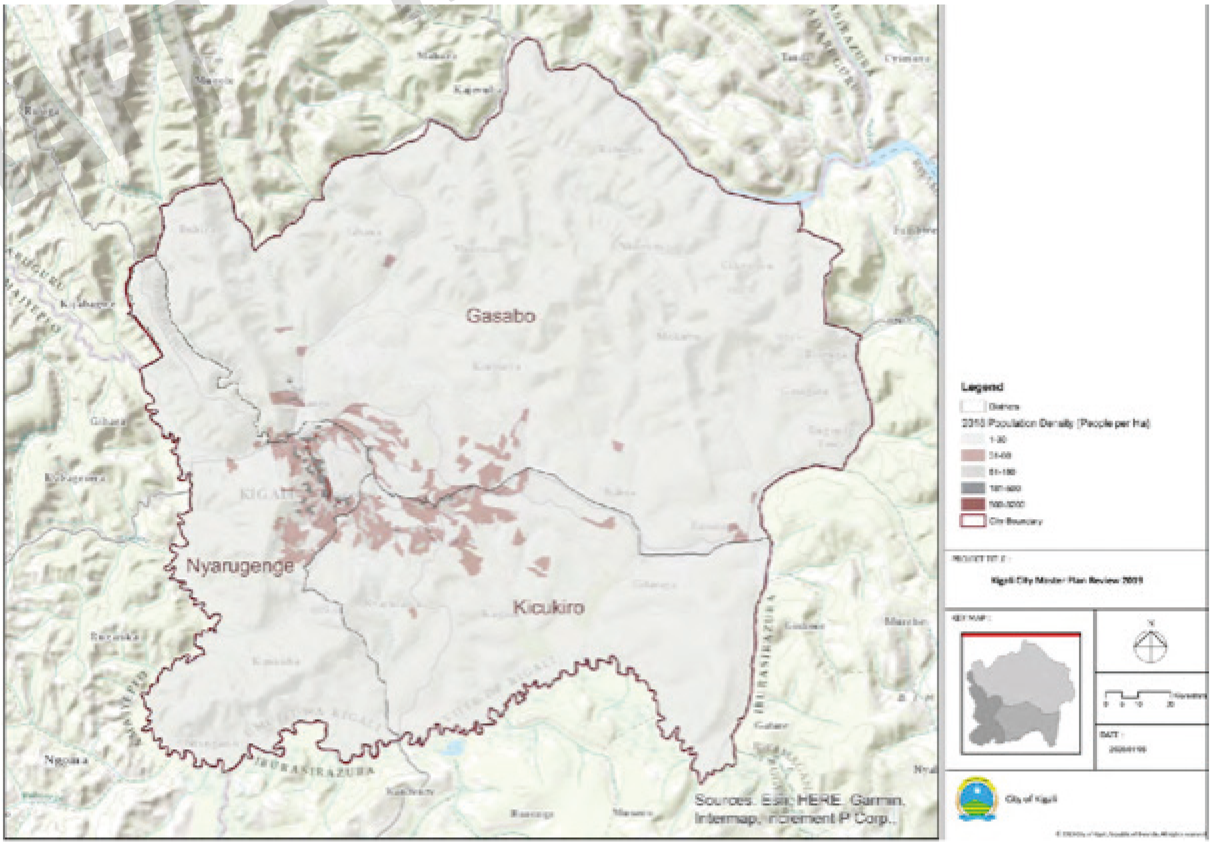


Figure 6-3: Population Density (People per Ha) in 2018(City of Kigali 2020)

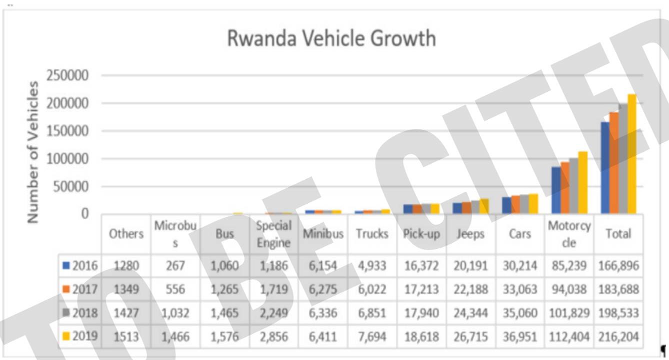
The total employment in the city in 2011 was 0.5 million, which is projected to be around 2.3 million by 2040. The central business district of Muhima, agricultural farmlands in Gasabo and Kicukiro, and free trade zone in Gasabo are the major contributors to Kigali's growing economy. Little more than 60% of the total employed population works in the services sector and around 35% for the employed work in the industrial sector and rest which is around 5% work in the agriculture sector. According to the Kigali economic development strategy report, around 37% of total employed are in agro-husbandry, 23% in the informal sector, 13% in the public sector, 8% in the private sector, 5% in the commercial sector and 14% in other sectors (Niyonsenga 2012, SPEA Engineering 2019).

This surge in city population has led to spontaneous, uncontrolled and haphazard development of the city of Kigali, according to the Kigali master plan document. As the city has been sprawling, it also has a very low development density with only 20 housing units per hectare. Consequently, 19% of the urban area of Kigali encroaches upon land unsuitable for development, for example, areas with steep slopes and wetlands(City of Kigali 2013).

The city's major economic sectors are challenged with issues ranging from congestion, pollution, deteriorating infrastructure, among others. The transport and energy sectors, especially, have become stressed over the years, thus, prompting major reforms. The city master plan has plans to support the vibrant and developing economy of Kigali city and its estimated 2.3 million jobs with the allocation of land for industries, commercial space and for housing purposes. The master plan strategies include a hierarchy of commercial spaces, strategic industrial zones, and low, medium and high-density residential land uses. These are supported by the development of community spaces, social infrastructure and health facilities. Thus, the Kigali master plan aims for decentralized nodes, transit-oriented development to support public transport (buses including dedicated bus lanes and BRT) and non-motorized transport (City of Kigali 2020).

Urban transport

The road network in Kigali, especially in the core, is continuously being improved. However, they need a good upgrade. In 2018 Rwanda had 216 thousand registered vehicles consisting of 52% motorcycles and 38% passenger vehicles, of which at least 30,000 are in Kigali (The number of vehicles is increasing rapidly (almost 12% per year)).



	Others	Microbus	Bus	Special Engine	Minibus	Trucks	Pick-up	Jeeps	Cars	Motorcycle	Total
2016	1280	267	1,060	1,186	6,154	4,933	16,372	20,191	30,214	85,239	166,896
2017	1349	556	1,265	1,719	6,275	6,022	17,213	22,188	33,063	94,038	183,688
2018	1427	1,032	1,465	2,249	6,336	6,851	17,940	24,344	35,060	101,829	198,533
2019	1513	1,466	1,576	2,856	6,411	7,694	18,618	26,715	36,951	112,404	216,204

Figure 6-4: Rwanda Vehicle Growth
Source: Republic of Rwanda, Statistical Handbook, 2019

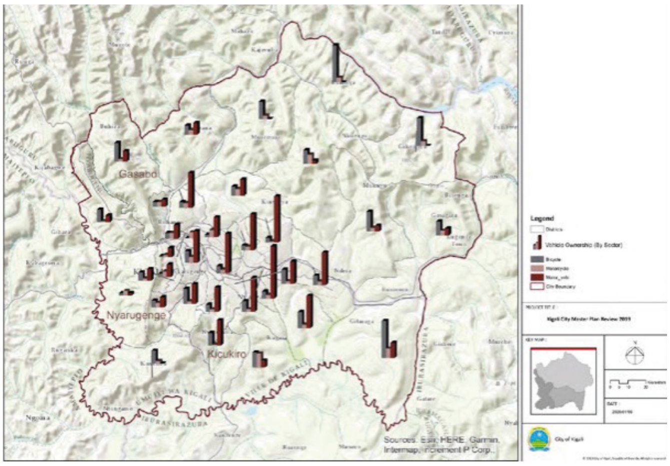


Figure 6-5: 2018 Number of households per sector that own at least one bicycle, one motorcycle and/or one motor vehicle(City of Kigali 2020)

Figure 6-5 from City of Kigali (2020) shows the number of households within a sector that own at least one bicycle, at least one motorcycle and/ or at least one motor vehicle. For example, some households might own more than one bicycle/ motorcycle/motor vehicle.   Also, one household might own both cars and bicycles.

In 2017 the total trips made in Kigali around 2.4

million trips were made in Kigali, with an average trip rate of 1.8 trips/hh/day. As shown in figure 6.6, more than half (around 52%) of these trips are undertaken using non-motorized modes, 17% by public transport modes, 16% by moto-taxis and the rest that is around 15% trips are performed by cars. In a BAU scenario projected by SPEA Engineering (2019) share of total trips made using a car is likely to increase to 41%, whereas NMT trips are likely to reduce to around 21% (SPEA Engineering 2019).

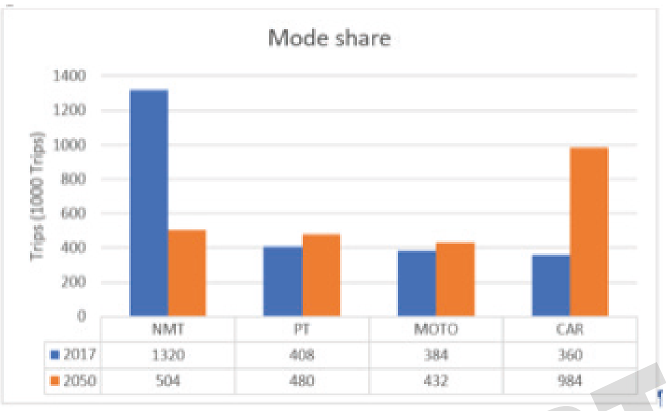


Figure 6-6: Mode Share (SPEA Engineering 2019)

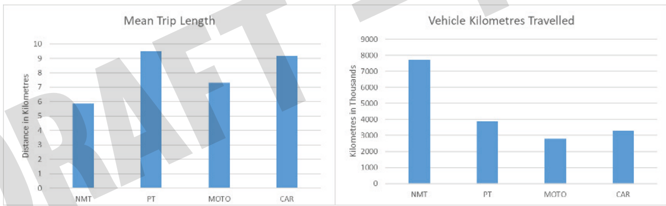


Figure 6-7Mean trip Length and Vehicle Kilometres Travelled/Modes(SPEA Engineering 2019)

The mean trip length in Kigali is around 7.4 km, and the mean trip length by each mode is shown in figure 6.7. As one would typically expect Kigali residents to travel while using a car or using public transport as a mode, the average trip length with NMT modes is around 5.8, which is relatively high compared to other similar cities in the World. Kigali residents travel around 17.5 million kilometres each day, of which around 10 million kilometres of travel with motorized modes of travel.

Figure 6.8 from City of Kigali (2020) shows the modes of transport that residents of kigali use as transport to commute to their place of work. These values correspond with the figures in figure 6-6 as most employed citizens use walking as a mode of transport to their place of work. The City of Kigali (2020) also states that areas where people earn a higher income, use private cars for commute purposes.

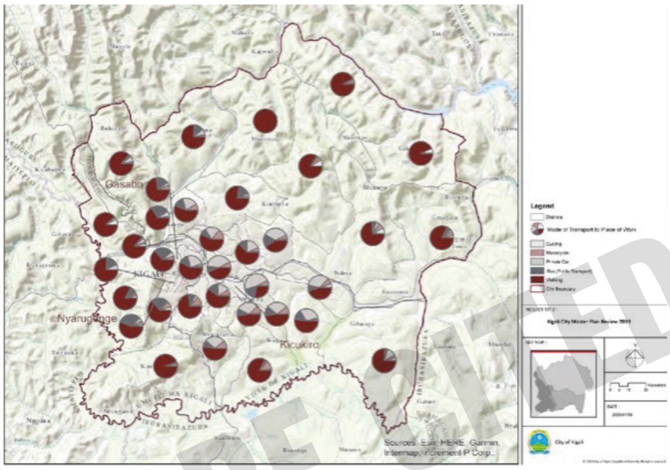


Figure 6-8: Mode choice commute to work(City of Kigali 2020)

Transport infrastructure, including coverage of public transport

The road network of Kigali city consists of around 2851 km of roads, of which only 16 per cent are paved. Kigali is also well connected with other parts of Rwanda by a network of national roads. In Kigali, the central business district (CBD) from the centre of the radial road network of paved roads(AfDB 2013).

The public transport system in Kigali is composed of Bus, Car Taxi, Moto Taxi, and Taxi bicycles (non-motorized). Licensed operators provide all motorized public transport services; however, tariffs are only regulated for the taxi-cars and bus services. This changed in August 2020, when Rwanda Utilities Regulatory Authority (RURA) announced tariff regulation for motorcycle transport services effective from 15 Aug 2020. Services are not operated on a pre-defined timetable, and there is some degree of flexibility accorded to bus operators concerning the routes, stops and buses operating on each route. Thus the public transport services operation in Kigali accords flexibility according to the demand.

The bus transport network in Kigali can be divided into four zones (figure 6.9), and operators need to sign a single contract with RURA; contracts have been awarded to three bus companies that is, Kigali Business Services (Zone 1), Royal Express (Zone 2) and Rwanda Federation of Transport Cooperation RFTC (Zones 3 and 4). These zones have been shown in figure 6.9. The RTDA Annual Report for 2016- 2017 shows there were 865.5 km of scheduled bus routes in the City of Kigali which was much higher than the RTDA Annual Report target of 330km for 2017.

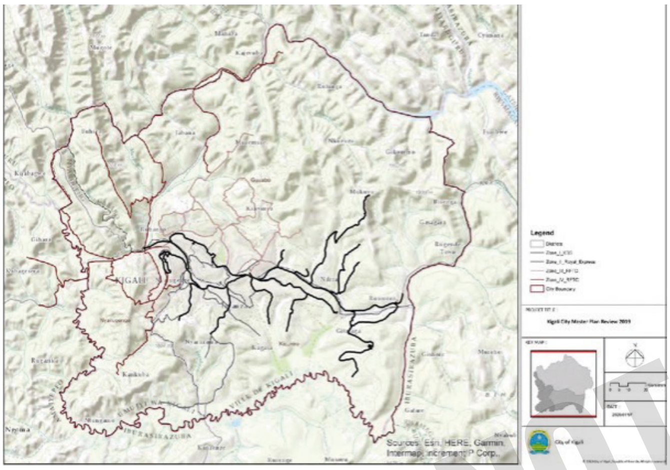


Figure 6-9: Public Transport in Kigali (City of Kigali 2020)

Identification of main problems

Passenger transport services

Issues highlighted in the 2020 Kigali Transport Master Plan

Public transport network	
Planning	Limited integration between public transport modes - Limited bus accessibility (unpaved roads, steep gradients); limited spatial coverage of the bus network - Limited space and government owned land for PT infrastructure - Limited shelters - No additional right of way for the BRT planned yet in the design for the new international airport PT link
Engineering	- Limited consideration of universal accessibility in the design of PT systems

Green transport network	
Planning	Dedicated pedestrian and cycle routes only provided in the city centre - Lack of continuity: disconnected non-motorized transport routes - Challenge of cycling because of hilly terrain (more than 5%)
Engineering	- Special needs not accommodated through universal access design

Freight transport services

Issues highlighted in the 2020 Kigali Transport Master Plan

Freight network	
Planning	Road freight: limited access for larger, heavier vehicles due to steep gradients; challenge of potential increase of e-commerce and traffic induced by deliveries - Rail freight: uncertainty over viability of rail freight to airport; technical and financial challenges of rail because of mountainous terrain; risk of creating a physical barrier if deploying a rail line in the city center

Overarching (road network, policy implementation)

Road network	
Planning	- Inconsistent road hierarchy, no classification system for local roads - Fragmented development - Many unpaved road - Road congestion, e.g. KN5 Road (International Airport) - Limited road capacity - Challenge of hilly topography
Engineering	- No formal guidelines to standardize the design of roads (no application of the EAC left-hand drive standards), road markings and signs - Problematic maintenance because of multiple traffic signals manufacturers - Poor design of traffic calming measures - Limited intersection control (only few traffic signals, no signal optimization) - Gradients not always considered in land-use developments/road access

Develop-ment	- Parking provision not systematically enforced throughout Kigali - Moto-taxi parking not included in planning
Effective transport policy implementation	
Planning	- Fragmentation of policy; gaps in responsibility - Lack of custodianship of the official city multi-modal transport model - Unclear hierarchy of transport plans - No centralized and updated transport database collating all survey data
Engineer-ing	- No guidelines for Traffic Impact Assessments for new developments - No thresholds and guidelines for pedestrian bridges
Develop-ment	- Buildings approved in areas where space for transport systems are required

Description of demonstration project

The demonstration action in SOLUTIONSplus focuses on electric mobility for last-mile connectivity in Kigali. It has a systemic approach integrating the public transport system with electrified feeder services provided by e-moto taxis (new and/or remodelled) and e-bikes. To facilitate connectivity, these e-bikes will be deployed within a bike sharing scheme along the most widely used bus corridors, with charging points fitted with solar power energy to provide seamless charging. In addition to these electric last-mile connectivity vehicles, the feasibility for electric buses will be explored with support from city authorities, transport operators and bus manufacturing companies. Expectedly, the project will create a good precursor to public transport electrification in Kigali. The demonstration project will support shared e-bikes (pedal bicycles) and e-moto taxi in developing business models, while providing policy and regulatory advice to public authorities. Finally, for the wider use of e-moto taxis and e-bikes, smart services applications that support Mobility-as-a-Service and eco-routing will be explored.

Relevant stakeholders and user needs

The SOLUTIONSplus Kigali team identified 36 experts under eight main stakeholder groups for the initial user needs assessment (UNA). Interviews were arranged and conducted with 9 of these experts. Online survey was also circulated among the stakeholders. Table 6.2 presents the contacted organizations 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 Kigali User Needs Assessment – City Report.

Aims of the city to transform urban mobility
Most stakeholders identified a plurality of goals pursued via e-mobility, including reduced carbon emissions, reduced air pollution, the introduction of innovative mobility options such as e-bikes (bicycles), as well as fuel reduction imports.

Reduce air and noise pollution, and help decarbonize transportation. All interviewed stakeholders highlighted the environmental advantages of electric mobility, especially in reducing air and noise pollution. Stakeholders observed that the introduction of e-mobility in the city centre and peri-urban areas would improve air quality - against the background of pollution of internal combustion engine (ICE) motorcycles not being controlled -, and that the introduction of e-buses would help to decarbonize transport in Kigali. Stakeholders also mentioned that e-mobility in Rwanda would help the country reduce imports of old vehicles that harm the environment. The interviewee with the regulatory authority felt that most developed countries are shifting from ICE vehicles to EVs, so the authorities intend to act as soon as possible so that Rwanda does not lag with old ICE vehicles.

Decrease fossil fuel import. Most stakeholders also opined that the introduction of e-mobility solutions in Kigali would reduce fossil fuel imports, and the adoption of EVs would reduce dependence on imported fuel. Stakeholders also felt that e-mobility would help the transport sector increase its reliance on locally produced energy rather than imported fuel.

Lower operating costs, economic benefits and comfortability. It is expected that the introduction of e-mobility will reduce operating costs and also increase comfort levels. Most stakeholders expect economic benefits via e-mobility in the form of increased electricity demand, spurred local production and reduced tariffs. On the positive side, with increased electricity demand, Rwanda has moved away from dependence on heavy fuel oil power plants to new electric supply sources and has also negotiated better tariffs with power producers. This will continue as the demand for electricity increases in future. The interviewees also stated that electric motorcycles are better in terms of speed and comfort than ICE motorcycles, and the interviewee is hopeful that the uptake of the new technology will be high.).

Regulations

The government plans to promote EVs in Rwanda and is in the process of drafting supporting measures fitting into the national transport policy. There is no e-mobility policy nor are specific regulations in place yet. Despite the current absence of policies, several stakeholders highlight the strong governmental support for e-mobility. Stakeholders are eager to see policies adopted. Several of them hope that they will be all-encompassing and will come with bold measures, including the provision of financial incentives and non-fiscal measures, such as allowing EVs to use bus lanes, free license plates, and special green license plates for EVs.

The interviewees also felt that the present challenge is the newness of the e-mobility technology, leading all stakeholders to learn along the way while upscaling, as well as a limited knowledge on e-mobility policies. They felt that the e-mobility landscape is very dynamic, and there is a need for testing policies before they are implemented at a large scale. Policies will have to consider that solutions may need to be differentiated for various vehicle types. For example, a good solution for a two-wheeler might not work as well for cars.

SOLUTIONSplus project expectations

Stakeholders identified several types of support that SOLUTIONS+ could bring in.
This included financial support to deploy additional EVs, financial support to extend the moto driver typology from men only to women and lastly, material support from the SOLUTIONS+ expert network (e.g. powertrains from EU industry partners). Stakeholders also expected that the SOLUTIONS+ project will increase EVs' visibility, translating into easier adoption of e-bikes in the long run, will support policy-making on sustainable mobility (e.g., bike lanes integrated with the planned BRT system) and bring in financial and technical support for e-mobility providers, not only for demonstration action but also to scale-up. The opportunity for SOLUTIONS+ to improve coordination between the multiple e-mobility projects and stakeholders, improving the image of non-motorized transport via the support to e-bikes, and facilitating access to funding, was also mentioned

Finally, respondents expected SOLUTIONS+ project to bring advanced solutions to ease maintenance of e-motorcycles, for instance, via an e-motorcycle demonstrator and training to local maintenance operators at local stations and garages. Further areas of support could include training in business operations and road safety.
Obstacles, limitations and barriers for EVs
Stakeholders highlighted several factors that can challenge the successful implementation of e-mobility in Kigali.

Charging stations: Lack of charging facilities and increased charging time for buses was felt as a potential limitation. An interviewee from the motorcycle-taxi sectors also mentioned that more charging stations would be required for e-moto taxi implementation.

Standards: The absence of charging standards could lead to safety issues, according to one interviewee. There is currently no clear masterplan, guideline, regulation related to the installation and operation of electrical charging stations for e-mobility. Stakeholders feel that policy will be needed on how the new charging infrastructure will be provided, including existing fuel stations.

Financial resources/upfront cost: Most stakeholders feel that investment in the sector is required, however access to finance (debt and equity) was a significant barrier. The upfront cost of buses, poses financial challenges that can affect e-mobility solutions' uptake.

Electricity tariffs: Although, as stated earlier, there is hope that the tariff will come down eventually, most stakeholders felt that the current high electricity tariffs would be the most significant challenge affecting the financial viability of e-mobility initiatives. Yet,although some interviewees stated that even with currently high tariffs, the shift to electricity is still financially attractive.

Supply chain and importations: Quality issues are also faced with supply chains and products from China, although incremental improvements have been achieved. EVs is a new technology, therefore switching from ICE engines to EVs will need many changes in the value chain. Regarding import policies, there are currently no particular regulations and guidelines on how EVs will be imported. However, the barrier of high import duties seems to have been partially resolved according to some stakeholders and service providers who received tax exemptions.

EV adaptation to topography. Several interviewees stressed the hilly terrain in Kigali, pointing out the necessity to assess the adaptability of EVs to this topography and impacts on operations.

Lack of technical expertise. There is concern about the availability of skills and knowledge to support the new technology, especially on e-buses, and maintenance of EVs in general.

Grid capacity. Views are disputed on this being a challenge. An interviewee with the public transport sector had concerns among stakeholders about electricity availability and felt that more electricity would be required for e-buses while other electricity-dependent services such as industries and residential are also growing. Nevertheless, this was not shared by other interviewees, including one respondent having led a study on e-buses, stating that its grid analysis showed that grid capacity was not an issue, except for large charging depots for buses in certain areas of the city, and one respondent providing e-moto services. The interviewee stressed that electricity is in surplus, though electricity distribution is not equitable.

More disputed: knowledge and awareness on EVs. As this technology is new, there is no information about e-buses, e-motos and e-bikes, which are not operating or operating to a limited extent in Rwanda. Some stakeholders also felt that there could also be behavioural barriers because people's mindset set to traditional ICE vehicles, making the switch to EVs difficult. Yet, this was not shared by e-bikes and e-motos service providers, stressing enthusiastic feedback on the vehicles.

Interpretation of interviews: the main challenges with regard to SOL+ project implementation
As the policy environment seems to evolve rapidly with expected measures on e-mobility, some of the main barriers could be lifted in the near future, such as high electricity tariffs. The political support for e-mobility solutions is a further facilitating factor, having led to flexible resolution of issues (e.g. importation duties) in the past. Yet, some context elements could turn as challenges for the implementation of the SOL+ demonstration action, such as the lack of coordination between initiatives and the absence of clarity on the involvement of the city authorities, as opposed to Mininfra. For the upscaling phase of the Kigali demonstration action, access to finance seems a persisting hurdle which should be addressed early, in coordination with other stakeholders. Generally, it seems that e-motos and e-bikes are well supported and with some positive results already (e-motos), while the hurdles and uncertainties faced by electric buses seem much higher, especially on the financial side. Lastly, the lack of technical knowledge and of information on pertinent policies does not appear as a barrier, but as an opportunity for SOL+ to fill a gap and answer well-expressed needs.

Business models

Regarding public transport, financed by private operators (nb. interviews done before the start of subsidization in the context of Covid), a shift from ICE to electric buses could be difficult unless there is financial support from the public sector. On the side of motorcycle-taxis, stakeholders mentioned the lower costs of e-motorcycles in terms of maintenance and transport energy, compared with regular motorcycles using fuel. The interviewee with the e-motos service provider (e-motos) stressed the positive impact of electric mobility on ICE moto drivers' revenues, citing figures of USD 1.84 per charge, 91 km range per battery swap, enabling a 108% percentage net benefit to drivers (informunication communicated during a conference in February 2020). The interviewee from the moto-taxi federation also mentioned that e-motorcycles under test in cooperation with one e-moto service provider are on the good stage of profitability. The business case and pricing structure for shared e-bikes were more uncertain, mostly detailing offers for students (100 RWF , i.e. about 10 cents USD, for 30 minutes, allowing them to cover a few kilometers). The interviewee from the e-bikes service provider claimed that shared e-bikes will be a cheaper alternative to moto-taxis (about 300/400 RWF, i.e., US $0.30-0.40, for sometimes 500m to 1km). More generally, some stakeholders found it challenging to identify the impact on users and business models without addressing costs for owning and operating EVs. Spare parts for EVs are prohibitive due to taxes, yet this seems to be changing via bilateral exemptions granted to service providers. The taxation and classification for e-bikes was unclear, possibly resulting in higher custom duties.

Finally, a need to incentivize the provision of charging infrastructure was identified, as well as work on recommendations on the building code to introduce charging at public buildings (green building minimum compliance standards).

Implications for Planning and Urban Development

Public transport planning. Stakeholders mentioned that there is a strong focus on the use of public transport and transit-oriented development in Kigali. The master plan encourages high commercial and residential density along mass rapid transit corridors. The interviewee from the OEM stressed that in Rwanda, many people still walk for about 20 minutes to access public transport. He feels that e-mobility solutions will have to be integrated mobility options (e.g. e-shuttles) catering for the last mile connectivity, all hinting towards a transit-oriented development.

Infrastructure planning. The need for an integrated approach was mentioned by several interviewees, alongside the need to understand better consumer behaviour and needs for charging. In addition, there is a consideration that data stemming from e-mobility may support better urban planning. The need to upscale the number of charging stations for e-motorcycle operations was mentioned by the interviewee from the moto-taxi federation - mentioned that current e-motorcycle operations are limited in Kigali due to a few number of swapping stations - and to include these in urban planning documents. In addition, the interviewee from the e-motos service provider mentioned the need to incorporate the additional space for infrastructure needed for electricity distribution and charging in urban plans.

Finally, parking is a topic with mixed views: the parking function was considered vital for charging by some interviewees, also mentioning that parking management will also be essential in a city where there is very little space. Yet, the policy context should be taken into consideration, with the 2020 Kigali Transport Master Plan stressing the need to reduce parking demand to limit the growth of private motorization.

Key Performance Indicators (KPIs)

Prioritization of KPIs addressing the specific city needs

As explained earlier, the stakeholders' priorities are determined by assigning weights to the selected Key Performance Indicators (KPI's). The KPI weighing activity in Kigali was conducted alongside the stakeholder interviews, the procedure for which has been described in section 2.1.4. Overall, nine interviews were conducted representing six stakeholder groups (academic, government, service providers, public transport, foundations and manufacturers).
The results presented here are the initial outputs as the aggregation procedures described in section 2.1.5. is not complete yet. Therefore the results presented here should be considered as initial outputs, which will be revised later when the steps mentioned in section are 2.1.5 are completed.

Figure 6.10 shows the mean values of the weights received from the stakeholders for the level1, level 2 and level 3 KPI's. Within each box, KPI values are shown in black text (relative weights) and red text (cumulative weights). 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 parent attribute's cumulative weight. The sum of all cumulative weights at each level is set to 100, and the cumulative weights of Level 1 KPI's are identical to the corresponding relative ones, only expressed at a different scale.

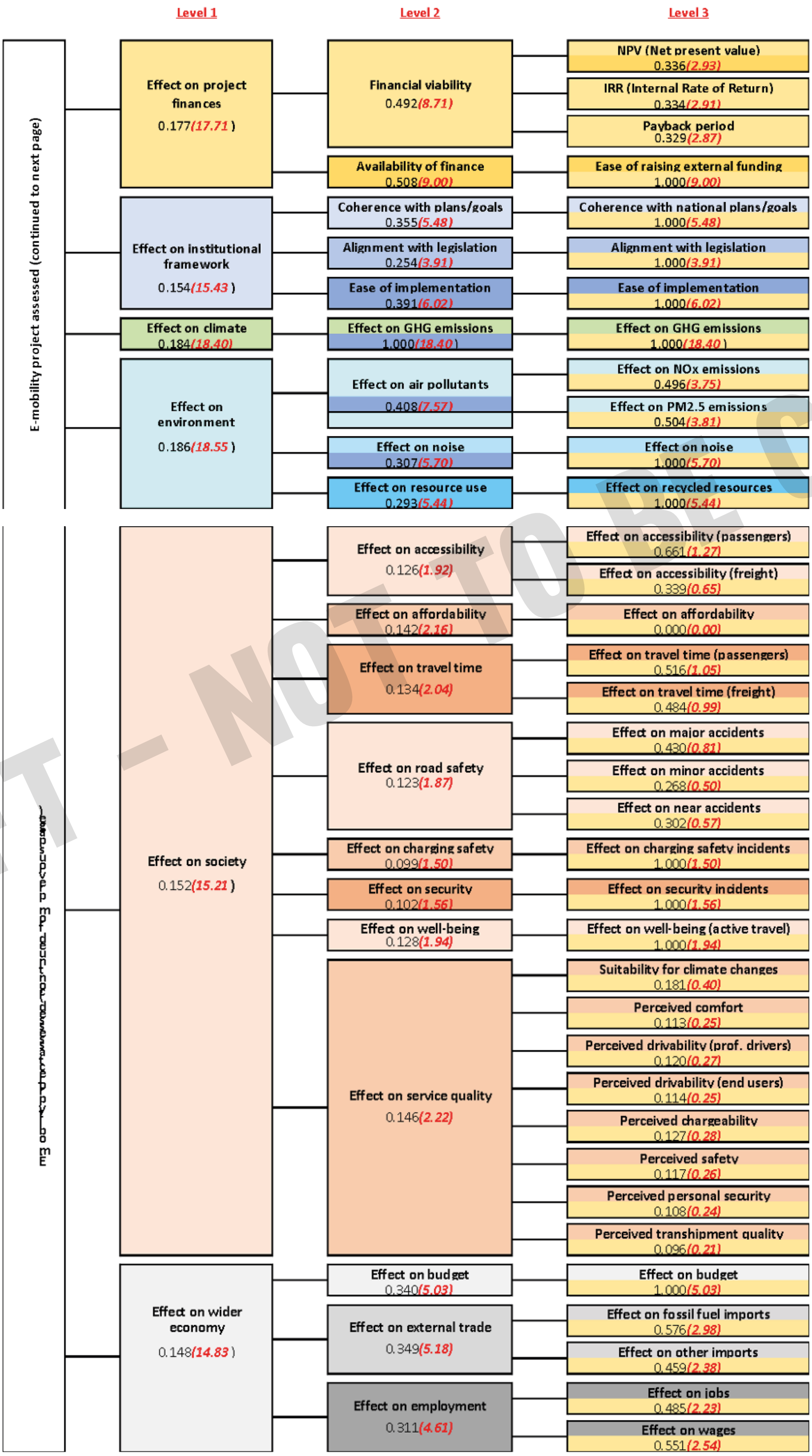


Figure 6-10:Attribute weights indicated by the Kigali stakeholders (tentative)

Effect on the environment and effect on the climate with a cumulative weight of 18.55 and 18.40 respectively appear as the stakeholders' main priority, apparently reflecting the importance of electric mobility for both the environment and climate change mitigation. Project finance is the third-highest priority underlying the importance of finance to support electric mobility initiatives. As also in the user needs analysis, institutions play an important role in the indicator weighting for Kigali institutional framework has been rated marginally higher when compared to the effect on society with a very small difference in weight (0.22). The effects on the wider economy (14.83) is given the lowest priority by the stakeholders. As stated, all stakeholders have not been consulted, and this process will continue. Therefore these value will be confirmed when the Delphi methodology is fully deployed, and the stakeholder feedback gets stabilized.

Among the level 2 indicators, some interesting observations can be made. Air pollution is accorded higher priority among the three 'effects on the environment level 2 indicators. Followed by noise pollution and environmental resources resulting from implementing the electric mobility project has the lowest priority among the environmental indicators. Among the institutional framework, ease of implementation is considered as most important by the stakeholders. Likewise, coherence with plans/ goals is also given very high importance by stakeholders. Thus, with the pending electric mobility policy in Kigali, there is a lot of hope that it will ease the implementation and help the city achieve its sustainable development goals. Among the effects on society indicators, quality of service, affordability and travel time come out as the parameters considered most important by the stakeholders. Highlighting the need for good quality, affordable service which improves acces-sibility by reducing travel time in Kigali.

In relation to the level 3 attributes, the importance accorded to climate again gets reflected in the high score (0.40) given to suitability for climate change among service quality indicators. Also, ser-vice quality, safety, and personal security are given high importance among the service quality in-dicators. Level 3 attributes of safety accord high importance to need to reduce major accidents.

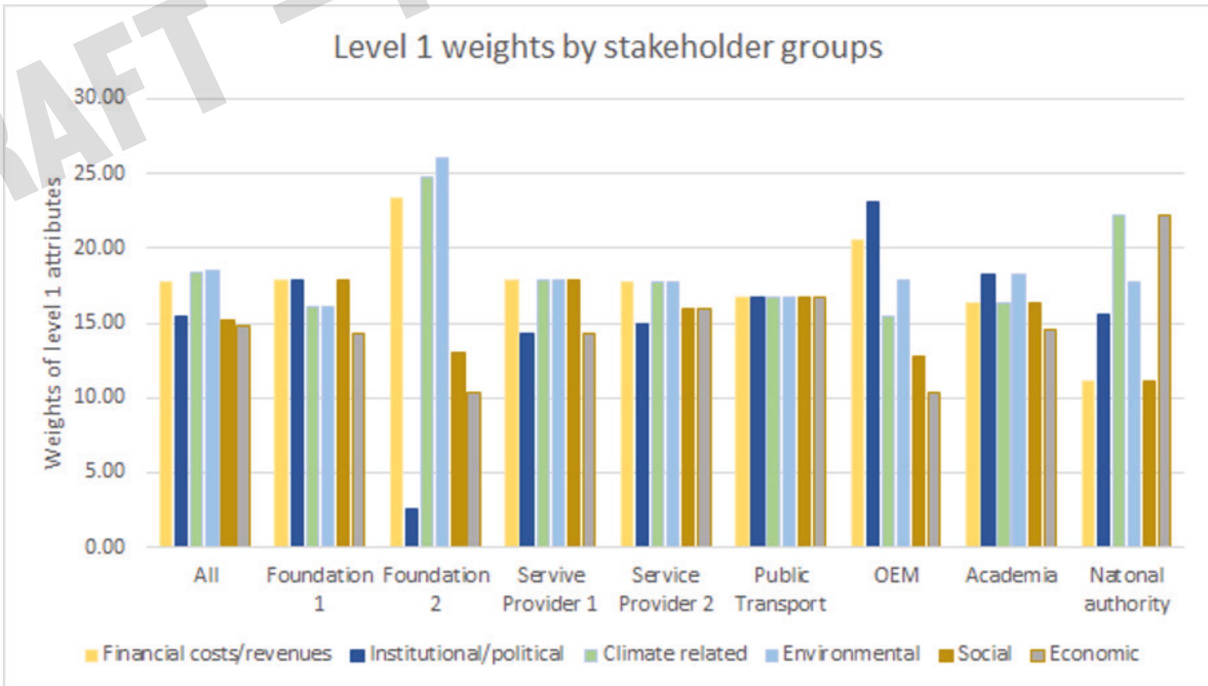


Figure 6-11: Level 1 Weights by stakeholder groups

With only eight stakeholders from six stakeholder groups presenting KPI results diss aggregated by stakeholders presented in figure 6.11 needs to be addressed with caution, the further discussion on indicator weight by stakeholder groups should be considered tentatively. Like all other KPI analysis, these will be updated when more stakeholders are added to the group.

- The foundation and OEM stakeholders assign high importance to finance, that is 23.4 and 20.5, respectively. These values are way more than the average 17.71 for the indicator. Comparatively, the national authority gives less importance to the financial viability of electric mobility projects. For the government, it seems that electric mobility projects are essential for the other benefits they carry, which out-weight the need for these projects to be financially viable.
- OEM and the stakeholder from academia accorded the institutional issues high importance. With scores of 14.3, 15 and 15.6, service providers and the national authority gave relatively less priority to the institutional issues over other dimensions.
- Even though the economic indicator has the lowest overall score, economic issues are accorded very high importance by the national authority with a very high score of 22.2, underlining the national authority's importance.
- For climate and environmental KPI's high importance is given by the foundation and the national authority. For the national authority, the need to mitigate climate change is as important as the economy with both having a score of 22.2. Foundation 2, is a research foundation, and, naturally, they consider climate change and the environment as the two most important issues with high scores of 24.7 and 26.
- Because the national authority and foundation 2 have given high importance to other issues, their scores for social KPI's are relatively low.

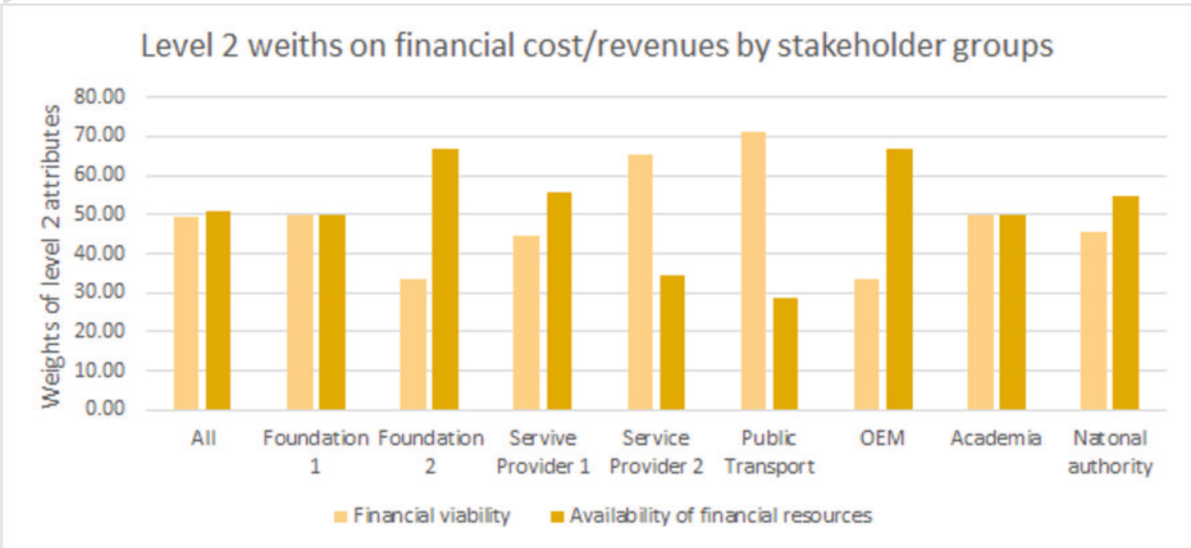


Figure 6-12 : Level 2 Weights by stakeholder groups - Financial cost/revenues

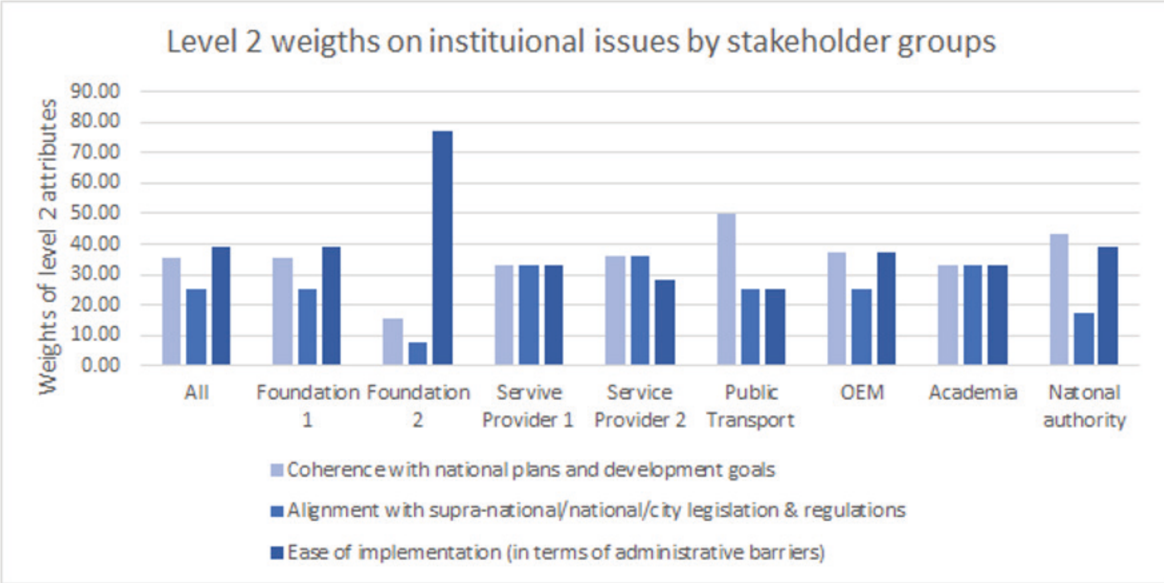


Figure 6-13: Level 2 Weights by stakeholder groups- Institutional Issues

Foundation 2, which gives high importance to climate and environment KPI's, also gives a very high score to ease of implementation among institutional KPIs, as shown in Figure 6.13. The stakeholder from academics and service provider 1 thinks that all three institutional issues are of equal importance. The public transport provider and national authority consider coherence with national plans and development goals to be slightly more important than needed for easy implementation of electric mobility projects.

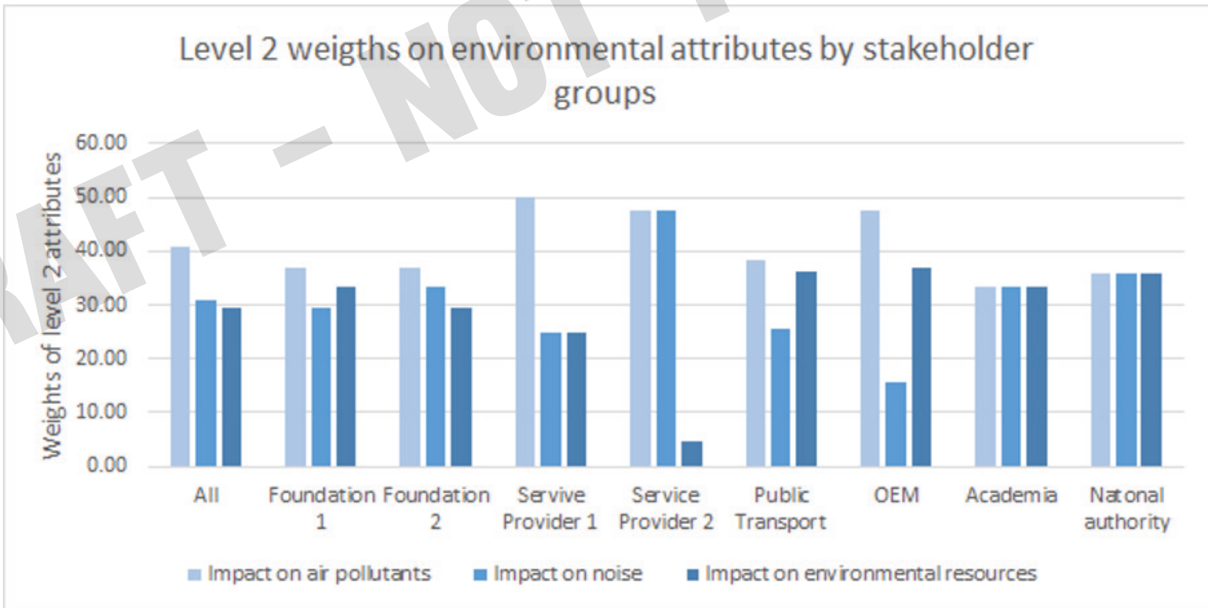


Figure 6-14 : Level 1 Weights by stakeholder groups - Environmental attributes

The stakeholders from academia and the national authority gave equal weights to all environmental attributes. As shown in Figure 6.14, all other stakeholders consider the impact on air quality as the essential environmental level 2 KPI. Surprising public transport operators and OEM gave relatively low weight to noise pollution and thought the impact on environmental resources was more critical in comparison.

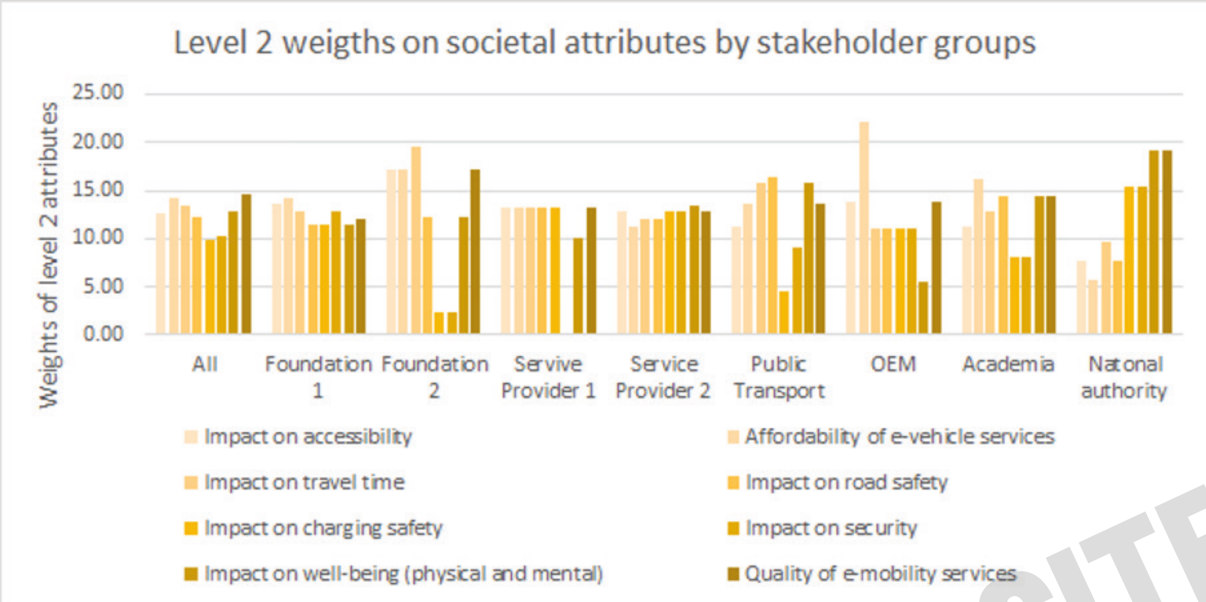


Figure 6-15: Level 1 Weights by stakeholder groups- Societal attributes

Foundation 2 and national authority gave very high scores to the quality of e-mobility services. Foundation 2, OEM and stakeholder from academia gave high scores to the affordability of e-mobility services; OEM stakeholder score was exceptionally high at 22.2. Foundation 2 and the public transport operation also considered the impact on travel time should have high weightage. Interestingly for the public transport operator as travel time has a direct link with ist patronage. Public transport operators also considered safety and well-being indicators more critical than other societal indicators like security and charging safety.

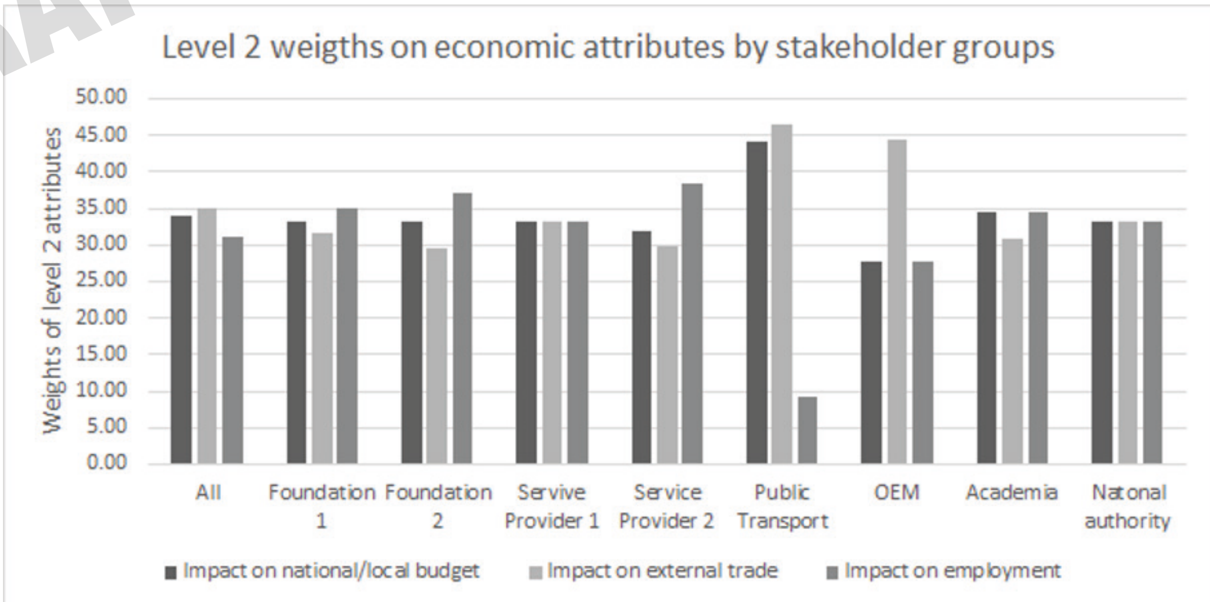


Figure 6-16 : Level 1 Weights by stakeholder groups- Economic attributes

National authority, as stated earlier, gave high importance to economic KPI's, but at level 2 they accord equal importance to all three KPI's. OEM operator and public transport operators consider the impact on external trade more important compared to other indicators. Likewise, service provider 2 and boht foundations consider that impact on employment should have marginally higher weightage compared to another level 2 KPI's.

KPI estimation methods and data needs

The present version of the document has only shown the data needed for the UNEP eMobility calculator that has been used to estimate Climate and Air Pollution KPIs. In terms of other KPIs e.g., road safety, environmental resources, national / local budget, etc. the data needed will be mapped after a formal definition for KPI is done.

To analyze the baseline scenario to project energy use, greenhouse gas and pollutant emissions , the tool developed by UNEP' e-mobility (eMOB) calculator' is used. The required input data for the model includes Socio-economic data (GDP and population), vehicle stock and sales, vehicle technology shares, economic growth and techno-economic vehicle parameters. Stakeholders and local institutions are expected to be involved in data provision and collection are listed in Table 6.1 by type of data needs. Incase of lack of exact data, assumptions were made.

Baseline scenario

The baseline scenario has focused on e motorcycles for the present version (31 Mar 2021). However other modes related to passenger transport buses, microbus, minibus and cars would also be covered in the next round. The focus of the demo is also on e bicycles for which there is no vehicle registration data and these would also be included in the baseline scenario.

Socio-economic data

Gross domestic product

Rwanda has a per capita GDP at current prices of USD 819 however it has grown steadily over the last two decades taking out a lot of people out of poverty. The data available from International Monetary Fund for Rwanda shows that GDP has grown at a compounded annual growth rate (CAGR) of 9.8% between 2000 and 2019 in terms of GDP purchasing power parity (PPP) in USD. The GDP statistics were not separately available for Kigali but as an urban centre the growth in per capita should be more than the national average however we assumed that per capita income for Rwanda as a whole and Kigali are similar.

The Rwandan economy also showed a good resilience in face of the COVID pandemic with the economy going down only -0.2% in 2020 and the World Bank projections show it will be again growing at 5.7% in 2021 and by 6.8% in 2022. There are no official projections available beyond 2022 for Rwanda and we assume a CAGR of 8% for the period 2022 to 2030. This high growth expectation stems from the strong growth witnessed by Rwanda prior to COVID.

Population

The population for Rwanda has increased from 8.4 million people in 2000 to 13.4 million in 2018 at a CAGR of 2.6%. In terms of future projections available from UN the population growth will slow down and grow at a CAGR of 2.1% from 2021 to 2030 and reach 17.8 million in 2030.

Kigali is a major urban centre of Rwanda and according to "The 2020 Kigali Transport Master Plan" had a population of 1.5 million for 2018 and forecasts a population of 3.8 million in 2050 which is a CAGR of 2.9%. Therefore Kigali is expected to grow much faster than the rest of the country.

Vehicle sales and stock

The data with regard to registration and de-registration is maintained by the Rwanda Revenue Authority (RRA) and according to that the cumulative registered vehicles, which reflect the stock of vehicles in the country has gone up between 2015 and 2018 from 166,896 vehicles in

2015 to 216,204 vehicles in 2018 at a CAGR of 6.7%. However motorcycles population during the same period increased from 85,239 in 2015 to 112,404 in 2018 at a CAGR of 7.2%.

The motorcycles in Rwanda play a very important role and account for more than 50% of vehicles and are used both as a means of public transport (as taxis) and by individuals as well. In terms of motorcycle in Kigali there is no time series data available however from literature we can find that there were around 30,000 motorcycle running in Kigali in 2018 . Therefore the national motorcycle population was downscaled at city level using this information.

Technology share of the fleet

The RRA data does not provide details in terms of vehicle technology however a recent study carried out by SWECO indicates that stock of motorcycles in 2019 was completely running on gasoline and uses the ICE technology . In 2020 however two motorcycle OEMs Safi and Ampersand were operational however since they are just starting the technology share in 2020 was put as 100% Gasoline ICE.

Techno-economic vehicle parameters
Annual mileage of motorcycles: The motorcycles are used both as a personal mode of transport and also as taxis and the annual mileage is very different. The annual mileage for private motor cycles is 9855 whereas if they are used motortaxis then the mileage is 40,827(Gustavsson et al., 2019)

Load Factor: The load factor was maintained as 1.6 as provided by UNEP.

Technical lifetime: As proposed by UNEP, the average technical lifetime of the motorcycles was taken 10 years however this needs to be confirmed from the data of registered vehicles since in case of cars the age distribution based on data provided by RRA shows a high share older vehicles (Figure 6-17).

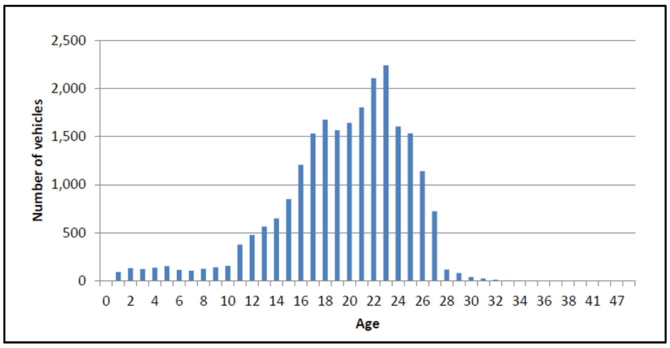


Figure 6-17 : Age distribution for cars registered between 2016 to June 2019
Source: Figure 9 from Gustavsson, et al., 2019

Fuel economy (FE) Gasoline ICE and Battery Electric Motorcycle: The motorcycle efficiency was taken as 4 lit per 100 km or 0.22 Kwh per km after Gustavsson et al., 2019. These appear to be a lower side, and therefore, an annual improvement of 0.9% is considered in vehicles. In contrast, the BEV motorcycle has a much higher efficiency of 0.08 Kwh per km (Gustavsson et al., 2019).

Sales share Gasoline and BEV motorcycles: As of April 2020 there were two motorcycle OEMs, Ampersand and Safi in Rwanda, and they are already running a few e-motos as taxis in Kigali. Ampersand claims to have logged 400,000 kms of running on these bikes (Bajpai and Bower, 2020) and considering an annual running of 40,000 kms for moto-taxis this comes out to a little more than 100 bikes. There are around 30,000 motorcycles in Kigali and this means a share of 3.3% in sales.

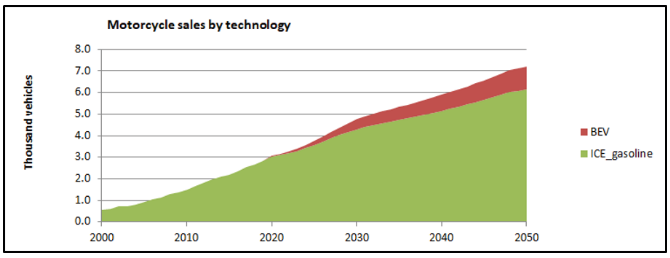
Vehicle emission standard and fuel quality standard: In 2020 Rwanda has Euro IV emission standard; however, the chronology of when the standards were implemented from 2000 onwards needed to be obtained from Rwanda Environment Management Authority (REMA).

Baseline KPI values

The vehicle trends and emissions for all the demonstration actions upto the year 2050 is projected, based on an eMOB calculator. The projections for e-motor cycles are shown below. Later the projections for e-bus will be added.

E-Motorcycles

Sales, stock and energy use upto 2050
Motorcycle stock in Kigali was around 30,000 in 2019 and by 2050 this is expected to go to around 70,000 motorcycles. In the baseline scenario it is expected that electric motorcycles will take some share from gasoline ICE motor-cycles



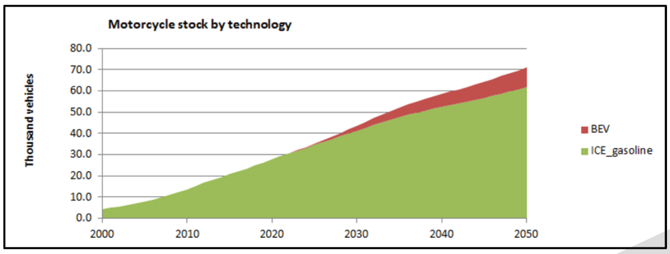
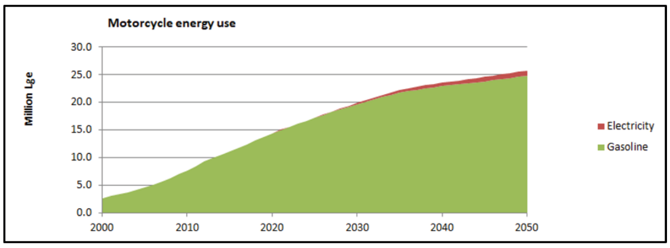


Figure 6-18: Vehicle stock by technology (projections)

Energy use and GHG emissions upto 2050
Sine the gasoline ICE technology is considered to dominate the share of motorcycle the energy mix is expected to be dominated by gasoline. However growth in energy demand will be slower than growth in motorcycle population e.g., though motorcycle population doubles between 2020 and 2050 the growth in energy is less than double. Due to this the growth CO2 emissions is also slower than growth in vehicle stock.



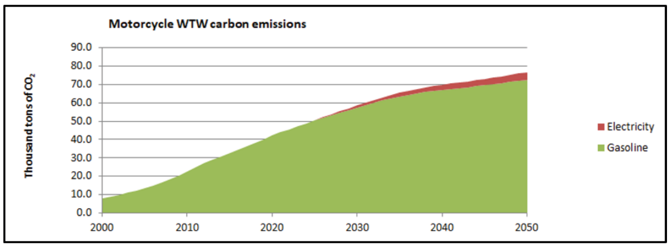


Figure 6-20: Motorcycle WTW carbon emissions

Local air pollutants
In contrast to CO2 emissions the PM and NOx emissions start decoupling from energy demand and this is largely due to the assumption that by 2030 Rwanda would adopt the Euro V and and by 2040 Euro VI emission standards. Electrification of motorcycles will also help in this regard since they have zero tail pipe emissions.

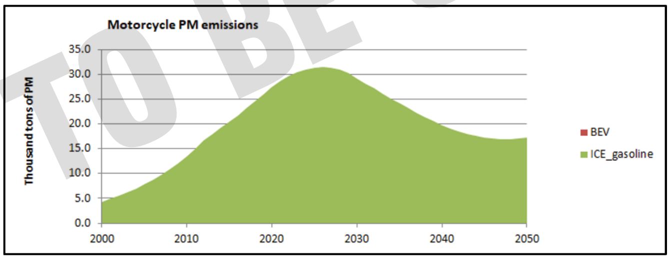


Figure 6-21: Motorcycle PM Emissions

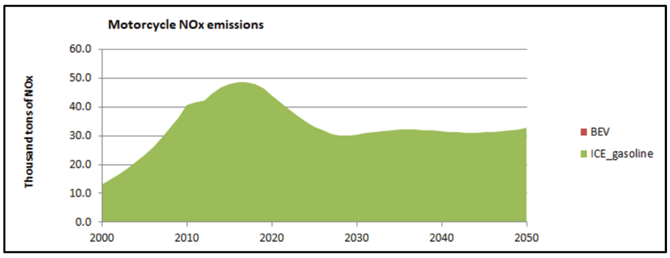


Figure 6-22: Motorcycle NOx emissionsExisting trends in passenger/freight transport

Ex-ante assessment of the SOL+ demonstration project

The stakeholder feedback discussed in section 5.1.4 serves as a strong validation of Kigali's demonstration actions. There is an urgency to increase the share of total trips made by electric vehicles, information sharing, need to increase the share of e-vehicles in public transport and knowledge sharing.

The demonstration action in SOLUTIONSplus focuses on e-mobility for last-mile connectivity in Kigali and can be considered pivotal to drive transformational change towards electric mobility where there is share electric vehicles in public transport and an overall high share of trips made on electric vehicles. The systemic approach integrating the Public Bus System with electrified feeder-services provided by 30 e-moto taxis (20 new and 10 remodelled) and 100 e-bikes that support first/last mile connectivity. With support from city authorities, transport operators and bus manufacturing companies, a suitable business model for e-Buses for the city's current bus transport administration will create a good precursor to public transport electrification in Kigali.

The demonstration project will involve existing transport operators, service providers and associations, including motorcycle taxi associations, bike rider groups and other relevant transport associations in Kigali. In partnership with local investors such as those outlined above, the demonstration project will introduce e-moto taxis in the city and support the installation of fast charging infrastructure at public places and vantage points. Other stakeholders of relevance to the project will include international vehicle manufacturers and local vehicle manufacturers and suppliers. The conversion/ remodelling of smaller vehicles exhibits substantial potential in transforming urban transport and will promote local industry and transform the last mile connectivity in Kigali. For upscaling of the proposed demonstrations, there risk associated with lack of money or financial resources and investment in infrastructure and development of a mature value chain, including the maintenance facilities. However, most of these apprehensions are because electric mobility is a very nascent stage, and value chains will develop, finance will come in, and values chains will mature with up-scaling of the electric mobility option. The impending electric mobility policy and the urban development plan Kigali are likely to provide the likely impetus for the upscaling of e-mobility.

Some topographic and climatic characteristics in Kigali may impact electric mobility:

- Hilly topography with steep slopes; variation between 1,300 and 1,600 metres average for the top of the ridges (City of Kigali 2013), evaluated between 1400 m and 1850 by Baffoe, Ahmad et al. (2020). Consequently, Ampersand integrates a starting torque of 200nm .
- Humidity ranging between 60% and 84% throughout the year; lowest temperatures between 14 and 16°, and highest temperatures between 26 and 28°
- Episodes of significant floods .

Given the key role that the bus conversion plays in the Kigali demo and its more advanced status, this stage's ex-ante assessment will be focused on this component.

Expected output

OUTCOME 1. Availability of high-quality e-mobility innovations is increased.

Baseline: In terms of vehicles, the current e-mobility solutions in urban areas are primarily limited to passenger transport. Charging solutions available to the public (as well as public transport operators) are still quite limited.

Target: High-quality e-mobility solutions (100 e-bikes and 20 E-moto taxi: ten new and ten remodelled) developed by local industries are made readily available to the market.

1.Locally produced vehicles (e-bikes and e-motorcycles) for last-mile connectivity are developed and tested

2. On-the-ground demonstration of vehicles for last-mile connectivity is conducted and assessed

3. Innovative charging facilities are demonstrated and assessed

4. Concept/pre-feasibility study for scale-up is developed*

OUTCOME 2. Conditions for enabling accelerated e-mobility uptake are improved.

Baseline: The current enabling environments for e-mobility (relating to business, policy, and financing) is still evolving. Initiatives that provide support in improving these aspects are generally welcomed.

Target: Suggest locally appropriate business models and plans; Establish specific linkages between local and European businesses; provide recommendations for enabling policies; provide recommendations for a national programme focusing on funding and financing

e-mobility
1. Business models and business plans are developed and validated
2. Interactions between EU industry and local businesses are established and documented
3. Recommendations for policy development, institutionalization and integration of e-mobility in local and national plans are developed
4. Funding, financing, and procurement for e-mobility program proposal is developed

OUTCOME 3. Local capacities relating to e-mobility are enhanced.
Baseline: As e-mobility is still in its nascent stage in the city/country, capacities are still highly limited.
Target: Local stakeholders' knowledge and capacities relating to different aspects of e-mobility are significantly enhanced.
1. Peer-to-peer exchange program is conducted and documented
2. Toolkit for e-mobility is developed and shared with local stakeholders
3. Local training activities directly related to the demonstration action is developed and delivered

The vehicle, operation and integration specifications below are suggestions based on the proposals received from Ampersand (motorcycle) and Gura Ride (electric bicycle).

Planned input
The input required for implementing the demo actions include:
- Human resources of various skills (electrical engineers and technicians, mechanical engineers and technicians, draft-persons, lathe and milling machine operators, quality control/procurement/administration officers, cleaners, etc.)
- Fixed assets (land and facilities)
- Capital goods (equipment and tools)
- Vehicle parts (old bus, electric powertrain, battery, other components, etc.)
- Specialized software

For the demonstration project's needs, it is assumed that no new facilities will be constructed or equipment/tools will be purchased. Thus, the marginal cost of such inputs is taken to be zero, despite the fact that this cost needs to be accounted for in the scaled-up operation.

The contribution of SOLUTIONSplus partner expertise is budgeted through different project budget lines. As such, only the locally provided human resources need to be included in the demo specific budget. The total value of the planned input is presented in Table 6.4.

Table 6.4 Budget for Demo projects

	SME call	City Equip. Budget	Industry partners
Staff time and inhouse facility	-	-	-
Design	-	-	-
Development of prototypes	-	-	-
Testing of prototypes	-	-	-
30 e-motorcycles (20 new and 10 remodelled)			
E-motorcycles (20 new and 10 remodelled) including batteries, GPS monitoring device, and other accessories	24,000	30,000	-
Charging Infrastructure and Installation	-	10,500	-
Helmets	-	1,250	-
100 e-bikes			
E-bike equipped with a smart lock and GPS tracker	8,325	27,100	-
Swap battery for bikes	2,775	15,725	-
Helmet for users	375	2,125	-
E-Locker charging station for battery	10,000	13,300	-
Bike dock station for pickup and drop-off of bikes	3,200	-	-
Powertrain Components	-	-	tbc
All other components	1,325	-	-
GRAND TOTAL	50,000	100,000	tbc

Expected effects

Financial and socio-economic profitability
Electric Bicycles (will be added lateron)
Electric motorcycles

A recent feasibility study for e-mobility in Rwanda conducted for KFW-FONERWA, Rwanda by JV Sweco ifeu (Gustavsson, Bergk et al. 2019), concluded that the total CAPEX cost of (Black, Barnes et al. 2018). For motorcycle taxi's the study assumes that a number of motorcycle taxis will be serviced from one central charging station with two different approaches and a battery swapping option(Gustavsson, Bergk et al. 2019).
1. Battery swapping system: one charg-

ing station where batteries are continuously charged and swapped when the motorcycle taxi's battery state of charge is low. Typically, one motorcycle would require 2-3 battery swaps per day of operation.
2. Depot charging: motorcycles are charged during the night time in different locations. The feasibility of this approach will depend on the operational length that the electric motorcycles can handle.
3. Fast charging motorcycles, typically at the charging station.

The study finds that electric mobility will be less costly than its corresponding ICE alternative in fuel economy. The study assumes that electric vehicles' maintenance cost is similar to those for a corresponding ICE vehicle. The maintenance may even be lower as there is no engine oil change required in an electric vehicle.

Electric motorcycles have a high upfront cost and lower operating cost corresponding to the petrol engine-motorcycle. The energy cost for the motorcycle is substantially high, which dominates its costs. However, the high cost of electric in Rwanda also results in high fuel cost for operating the electric motorcycle.

Electric buses
In the Gustavsson, Bergk et al. (2019)study, the economic estimations, capital expenditure (CAPEX)/operating expenses (OPEX) have been performed for four different electrical bus cases. Four cases have been analyzed.
- The electric bus with overnight charging has been assumed to have a large battery sufficient for the complete daily operation. One single charger will be installed at the washing base. Optionally, a shorter charging mid-day could be planned if needed and low transport needs
- The electric bus with end station charging has been assumed to share the charging station with four other buses. Additional overnight charging would be arranged occasionally, without additional costs included but rather as a part of maintenance work.
- The trolleybuses are assumed on one single bus line, needing 18 km (Jali holding 2019) trolley power grid covering 18 buses. This is a very specific assumption which would have to be further verified in deeper analysis in the Kigali case.
- The In Motion Charging (IMC) system only needs a power grid for approx. 50% of a bus line operation (depending on local prerequisites.). IMC is assumed to need 15 km of the power grid to cover the central path ways for in total 100 buses. However, this case has to be analyzed in more detail to be closer to the real Kigali situation

The resulting calculations show that all the electric bus cases are more expensive than the conventional diesel bus case. The most expensive case seems to be the trolley case. However, it very much depending on the number of buses on the specific line. The most cost-effective in the EV case seems to be the end station charging. The operation costs are higher than capital costs in all cases. The main differences in the vehicle's cost (without battery), which is 1.5-2 time higher compared to an ICE diesel bus. In terms of cost per year, batteries' cost is a substantial cost for the buses, increasing the electric buses' per year cost.
The values in tables xx and xx are financial costs and do not include socio-economic costs.

They include:

- Economic cost: The cost of Rwanda's total dependence on foreign sources for fossil fuel imports.
- Social cost: Health costs associated with the air and noise pollution caused by the combustion of ICE engines
- Environmental cost: Climate change costs due to the GHG emissions generated by the combustion of fossil fuel

The benefits of using an electric vehicle can be substantially high, even though these benefits have not been quantified financially. The Gustavsson, Bergk et al. (2019)report highlights the importance of electric vehicles in reducing energy needs. The gasoline demand can be reduced by 21 % and diesel by 9 % until 2030. The total demand for oil products is reduced by 15 % (minus 2,676 TJ final energy demand). Due to the higher efficiency of electric vehicles, electricity demand is only increasing by 480 TJ, respectively 133 GWh of electricity.

The Gustavsson, Bergk et al. (2019) report also compute the overall reduction of GHG (WTW) passenger transport emissions thanks to the e-mobility measures of about 17 % (182,000 t CO2eq) compared to the BAU. Wherein motorcycle taxis have the highest relative reduction with 47 % or 47,000 t CO2eq. Public transport (excl. taxis) is also a significant driver for the absolute emission reduction of the scenario, reducing buses and minibuses of 55,000 t CO2eq in 2030, which align well with the demonstration action proposed in the Solutions+ project. Therefore, one can expect similar environmental benefits upscaling of the demo action proposed in the project.

Alignment with legislation

As the EV policy is still being prepared, there is no local regulation that addresses EVs' category in Rwanda. However, the e-mobility study identifies a need for the following standards.

Vehicles	Incentives and regulations for new and second-hand imported vehicles (including motor vehicles)
Charging	Standardize connections to charging points via for example, CHadeMo, follow the EU-regulation in this field or IEC 62196", charging design, safety and operational aspects; regulations for import of renewable energy generation components (e.g. solar panels)
Others	Gaps to be filled in current regulations e.g. safety laws, taxation laws, etc.

In its Work Plan for July-December 2020, the Rwanda Standards Board included ongoing work on a Rwanda standard (i.e. not regional) entitled "Electric vehicle charging stations – Requirements". This standard will be elaborated within the Technical Committee RSB/TC 50 Electrical Energy, Equipment and Accessories, under a preparatory stage by October 2020, coming into the committee stage by December 2020. The references for this standard are:

IEC 62196-1:2014	Plugs, socket-outlets, vehicle connectors and vehicle inlets – Conductive charging of electric vehicles – Part 1: General requirements
IEC 62196-2:2016	Plugs, socket-outlets, vehicle connectors and vehicle inlets – Conductive charging of electric vehicles – Part 2: Dimensional compatibility and interchangeability requirements for AC pin and contact-tube accessories
IEC 62196-3:2014	Plugs, socket-outlets, vehicle connectors and vehicle inlets – Conductive charging of electric vehicles – Part 3: Dimensional compatibility and interchangeability requirements for DC and A.C./D.C. pin and contact-tube vehicle couplers

It is expected that the new electric mobility policy will be published in 2021, and all the relevant regulations will be in place. The demonstration actions carried out within the Solution+ project will also give direction to the process.

Effect on GHG emissions

On average, each motorcycle taxi does around 41,000 annual vehicle kilometres. Likewise, a Bus does 65 953 kilometres per year (REMA 2019).
Electric Bicycles (will be added later on)
Electric Motorcycles

Therefore, the 30 e-motorcycles that are planned as part of the Solution+ project will run for around 1230000 vehicle kilometres per year. The gCO2eg /pkm emissions from a motorcycle-taxi is around 240 gCO2eg /pkm, and from a battery-operated motorcycle taxi, it is around 60 gCO2eg /km (charging mode) and 65 gCO2eg /km (battery swapping mode) Gustavsson, Bergk et al. (2019). Thus assuming that passenger occupancy as one for motorbikes for every motorbike 7.4 tCO2eg/year can be saved, for 30 demonstration moto-taxis, 222 tCO2eg/year can be saved. If we assume that around

40% of the current moto-taxi stock of between 20,000 to 30,000 moto-taxis converts to e-moto taxis 74,000 tCO2eg/year can be saved.
Electric Buses

Likewise, for buses, ICEV diesel bus emits around 55 gCO2eg /pkm, whereas electric bus will emit around 35 gCO2eg /pkm(Gustavsson, Bergk et al. 2019). An average bus in Kigali operates for around 66,000 km per year. Assuming a vehicle occupancy of 25 every bus that is converted to electric can save 33 tCO2eg/year. If the proposed BRTS system uses all-electric buses, then in 2030, for a passenger-km demand of 756849 x 103 passengers, the total tCO2eg saving will be 15137 tCO2eg/year
Effect on NOx emissions
The converted e-bus combined with renewable electricity will ensure the elimination of NOx emissions. The quantities involved will depend on the emission standards of the existing fleet and require further research.
Effect on PM2.5 emissions
The expected effect on PM2.5 emissions is also a function of the emission standards of the existing fleet and, as such, will be estimated upon collection of the relevant data.
Effect on noise

Electric Bicycle (will be added later on)

Electric Motorcycle

Electric motorbikes operating as motorcycle taxis is an attractive concept in the Kigali area. The introduction of the e-mobility solution will improve the air quality and reduced noise will be experienced. Sheng, Zhou et al. (2016)have studied human exposure to traffic noise and took into account the contribution of motorcycle traffic. The results indicated that electric could be an appealing solution to reduce the risk of human exposure to excessive-high traffic noise in Macao's motorcycle city, choosing two different urban areas with distinct urban form, one traditional urban design and one with modern urban design.

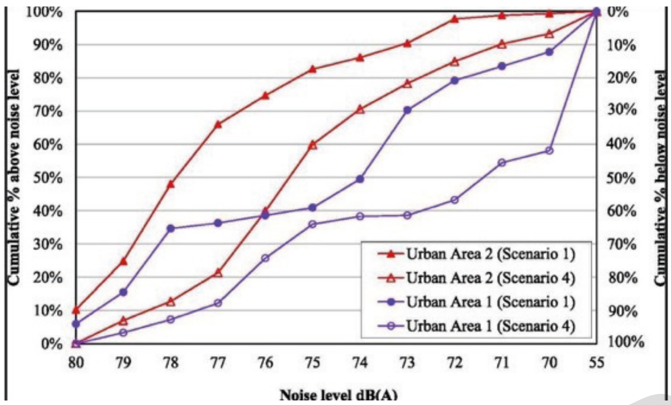


Figure 6-23: Effect of an electric motorcycle on noise pollution(Sheng, Zhou et al. 2016)

In Scenario 1, the existing traffic is considered, and the noise level is modelled using 2398 receptors. In Scenario 4, it is assumed that EMs replaced 100% of gasoline motorcycles in the real traffic scenario (Scenario 1). From figure 6.23 it is clear that in scenario 4 for both cases of urban areas, there is a significant improvement in the noise levels. Macau has similar motorcycle levels as in Kigali. Therefore in Kigali, we can expect significant improvements in the noise levels after converting the ICE vehicles to e-vehicles.

Electric Bus

Effect on recycled resources
In addition to its other effects, the bus conversion component is expected to contribute to more sustainable use of materials and the promotion of the circular economy concept in the framework of SDG 12 (Ensure sustainable consumption and production patterns). As recommended in IGC (2020), environmental standards for the recycling and of batteries and electronic waste should be developed alongside the e-mobility policy.
Effect on affordability

Safety

According to police data, Kigali City road-based accidents remain higher than the rest of Rwanda. In 2017, 71% of total registered road accidents involved motorcycles (moto-taxis), pedestrians and bicycles. As can be seen from figure 6.24 the main road and city circle junctions remain the hotspots for fatal accidents in Kigali, as determined from a study done from the police database. The information was extracted from the 2017 Rwanda Statistical Yearbook. No data was available to distinguish between accidents involving pedestrian and cyclists. The government has continued to implement safer road programs to educate road users on the road's effective and safe usage. In 2017 the government reviewed laws on the road. As shown in Figure 6.25, motorcycles have the highest safety-related incidents, with both injuries at 55% share and fatalities at 37% share. They are followed by public transport vehicles. Solution+ project plans to promote both modes. Therefore it is essential that safety parameter are given careful consideration.

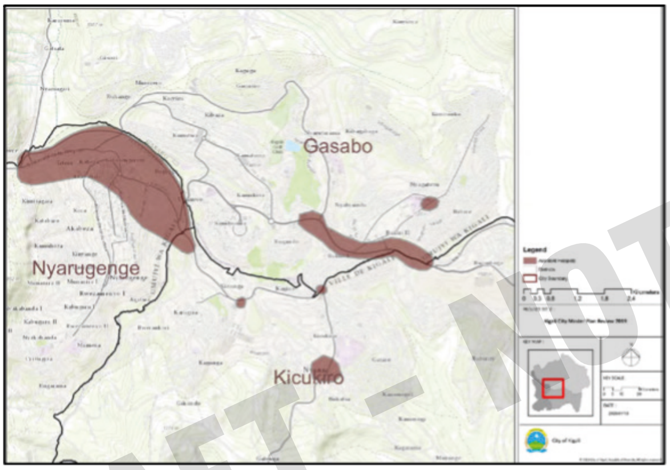
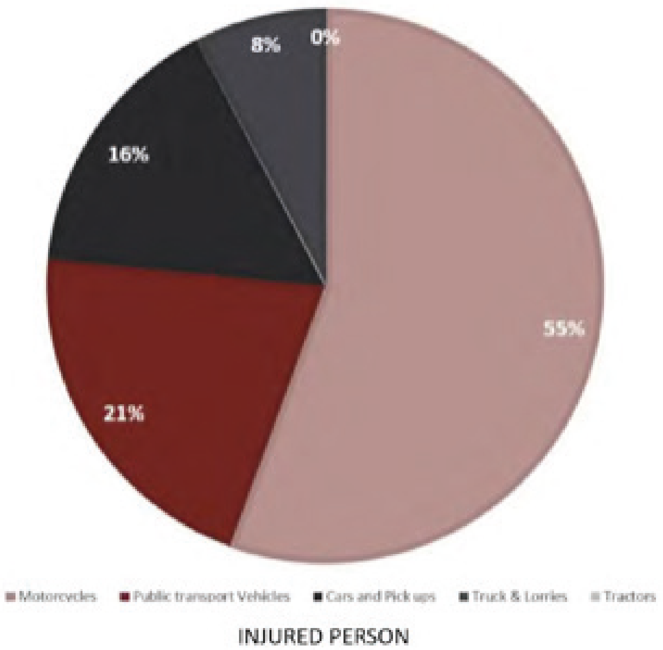


Figure 6-24: Fatal accidents hotspots(City of Kigali 2020)



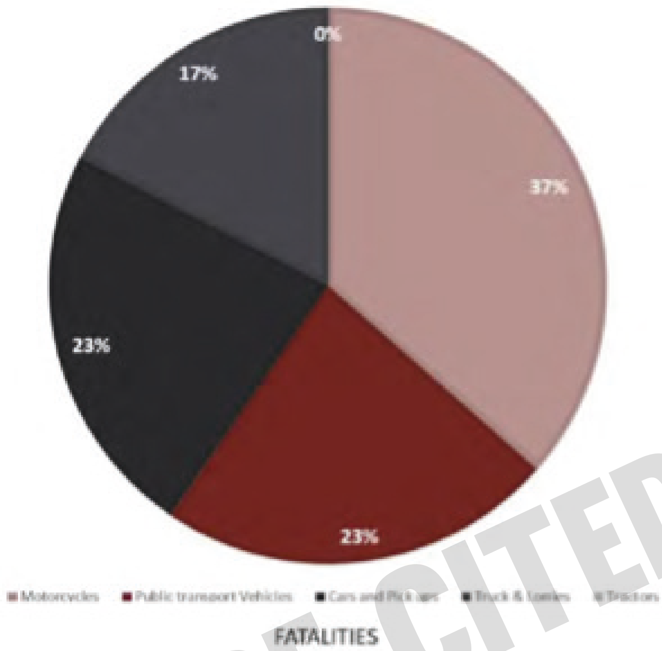


Figure 6-25: Injuries and Fatalities by Mode type

Effect on charging safety

Many of today's motorcycle repair shops e,g. have the lowest possible availability of tools, even meters, to recognize electricity failures are missing (Sweco, 2019). Several actions need to be put in place before electric mobility can be scaled up and the number of vehicles increased. Further actions are needed, including that technical standards and regulations cover charging infrastructure design, safety and operational aspects, and that pilots are used to learning and adjusting approach. Charging infrastructure studies are needed for different vehicle categories, including testing charging strategies and assessing the feasibility of these solutions.

DRAFT - NOT TO BE CITED

This is an interim draft that has been completed prior to the implementation of demonstrations in cities and was finalised based on individual city reports (status as of 31 March 2021)

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