Feasibility study on the modification of pedal driven rickshaw to electrically assisted rickshaw to improve the health and earning capacity of the rickshaw drivers in Kathmandu.

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Executive Summary

Pedal rickshaw drivers in Kathmandu, whether they own or lease their rickshaw, rely on it as their main source of income despite the fact that it offers little financial security. Earnings for rickshaw drivers can vary depending on demand from customers, affecting their daily working hours and subsequent earnings. Furthermore, operating pedal rickshaws is physically demanding, which requires rickshaw drivers to be in good physical health to work enough hours to earn well. Any health issues that compromise physical well-being have a direct impact on daily earnings.

The results of Environmental Performance Index (EPI) mentioned that Nepal's air quality is worst among the 180 surveyed countries. Nationally Determined Contribution for Nepal shows that by 2050, Nepal will decrease its dependence on fossil fuel in the transport sector by 50% through mass public transport, while promoting energy efficient and electric vehicles. Considering these facts, electrically assisted rickshaws, although will not able to bring radical change in the national transportation system, will contribute in Nepal's goal to develop electric vehicles. Smaller vehicles such as electrically assisted rickshaw can serve the community to provide benefits to the rickshaw drivers and customers without causing harm to the environment.

The solution this study proposes is to modify six pedal rickshaws in Kathmandu using an electric assist system to reduce the physical strain and hardship of operating rickshaws while also improving the earning capacity of the drivers. The study has the potential to directly impact those at the bottom of the pyramid - poorest socio-economic group.

Despite the mechanical, behavioural, policy and supply chain challenges during the study, observations and analysis shows that low cost modification of pedal rickshaws into electrically assisted rickshaws can reduce physical strain and health problems or rickshaw drivers. In addition, they shorten trip duration and so make more trips possible in a working day, or potentially increase leisure time for the driver. Findings further reflect that although actual income did not increase with use of modified rickshaws, there were improvements in health outcomes and factors that directly affect income earning potential.

These factors collectively have a positive impact on the drivers' income earning capacity, health and wellbeing. The product needs to incorporate new changes for efficient operation otherwise the issues of repair and maintenance will add to the economic burden of the rickshaw drivers.

Electric assisted system was selected because of the low operational costs (a few electrical units to charge), zero emission during operation and a small capital investment (modification cost in Nepali Rs 80,000, USD 717.10[1]).

This report shows the benefits of using electrically assisted rickshaws over pedal driven rickshaws. It can be a basis for drafting new policies related to the modification of the pedal driven rickshaws.

[1] As per Nepal's central bank - Nepal Rastra Bank (on 13/05/2019), USD 1 = 111.56

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I. Introduction

A. Background

The origins of the word 'rickshaw' lies in the Japanese language, meaning "a human powered vehicle" [1,2]. Rickshaws are believed to be first seen in Japan in 1868 [3]. During this time, rickshaws were pulled by people with two sticks projected from the cabin mounted on wheels. Pedal rickshaws were believed to be first introduced in 1929 in Singapore when a bicycle was innovatively added to the body of rickshaw [4]. They were introduced in Nepal in the mid-20th century. However, few to no technological improvements have been made to rickshaws since its introduction in Nepal with people still pedalling using their physical energy.

There are approximately 20,000 pedal rickshaws in operation in Nepal, of which over 2000 operate in Kathmandu. In Kathmandu, 472 people carrier rickshaws are registered but only 200 are in operation. They serve as a popular mode of transport for tourists and locals over very short distances, limited to certain parts of the city. However, over 1500 rickshaws (registered and unregistered) operate as cargo carriers in Kathmandu (G. Rawat[2], personal communication, January 15, 2019). Cargo carriers serve a broader commercial purpose as inexpensive modes of transport, carrying goods and materials (weight less than 500 kg) within the city.

Most pedal rickshaw drivers, whether they own or lease their rickshaw rely on it as their main source of income despite the fact that it offers little financial security. Earnings for rickshaw drivers can vary depending on demand from customers, affecting their daily working hours and subsequent earnings. Furthermore, operating pedal rickshaws is physically demanding work which requires rickshaw drivers to be in good physical health to work enough hours to earn well. Any health issues that compromise physical well-being have a direct impact on daily earnings. Unfortunately, these rickshaw drivers are more likely to suffer injuries and health problems because of the nature of their work. Undernourishment and physical strain on the body from long hours of carrying heavy loads are commonplace [5] .

Bearing these realities in mind, the solution proposed in this study is to modify six pedal rickshaws in Kathmandu using a powered assist system to reduce the physical strain and hardship of operating rickshaws while also improving the earning capacity of drivers. The study has the potential to directly impact those at the bottom of the pyramid. In terms of the existing rickshaw technology, different power assist systems such as mechanical (air compressors, flywheels), engine (2 or 4 stroke engine) and electrical (batteries, motor and controller) are used in different contexts, globally. For the purposes of this study, an electric assist system is used to modify the existing pedal rickshaws. This system is used because of the following reasons:

- *Electric vehicles fall under priority for the Government of Nepal (GoN).*
  Nepal's Nationally Determined Contribution (NDC) includes ambitious targets for low-carbon sustainable transport. Of the 14 targets mentioned in the NDC document, four of them prioritise electric mobility within the transport sector in Nepal. There is opportunity to scale the use of electrically assisted rickshaws under the NDC target to increase the share of electric vehicles to 20% by 2020 [6].

[2] Gyanu Rawat, Nepal Thela Rickshaw Sramik Sangh, Kathmandu

- *The electricity used to charge the batteries in our kits will be zero emissions.*
  Nepal is reliant on hydroelectricity with more than 90% of electricity generated in Nepal being from hydropower in the fiscal year 2017/2018 [7]. Charging from hydroelectricity results in lower negative environmental impacts such as air pollution. Vehicle emissions are a major source of air pollution in the Kathmandu valley, and claim an estimated 9,000 lives per year across Nepal. It is also responsible for loss of welfare of over USD 2.8 billion [6].

- *Feasibility of building electric kit (e-kit) in-country by importing mechanical components.*
  The e-kits required for modifying the pedal rickshaws are available in China, which is in close geographic proximity to Nepal.

  Table 1 outlines the different types of rickshaw technology and various components of the e-kit. As discussed earlier, this study focuses on retrofitting the pedal rickshaws using an electrically assisted system.

Table 1: Rickshaw types and definitions

Pedal rickshaw - manually operated cycle rickshaw
Electrically assisted (e-assist) rickshaw - existing pedal rickshaw modified using an electric assisted system
Electric rickshaw (e-rickshaw) - solely runs on an electric system
Pedicab - includes both pedal and electric system and is a brand new vehicle

B. Aim and Objectives

The focus of this project is to conduct a feasibility study for electrically assisted rickshaws in Kathmandu. The main aim of this study is to explore whether improving the mechanical performance of pedal rickshaws will enhance the socioeconomic conditions of rickshaw drivers such as their health and income earning capacity status.

The objectives of the study are to:

- Modify up to 15 pedal rickshaws with e-kits. However, only 6 pedal rickshaws were modified due to mechanical and regulation challenges explained in the findings and limitations sections.
- Identify the demand and potential scope for operating electrically assisted rickshaws in Kathmandu.
- Develop a business model for electrically assisted rickshaws and outline the different costs involved in the modification and operation.
- Provide evidence of positive socioeconomic impact generated through the modification of pedal rickshaws, to various authorities such as municipalities, Department of Transport and Management (DoTM) and traffic. Based on this evidence, it is anticipated that governing bodies will develop policies for registration and legalisation of electrically assisted rickshaws in Kathmandu.

- Outline a conducive supplier's network for e-kits, exploring different options to import the e-kits and ways to locally manufacture electrically assisted rickshaw mechanical systems.

C. Research Process

For this study, literature review and six case studies were conducted. The gap analysis and concept generation emerged from literature. A case study method was adopted for this research; it is an empirical inquiry that investigates a phenomenon in the real-life context [8,9]. The study describes and explains the background, developments and challenges of operating electric assist rickshaws in Kathmandu through quantitative and qualitative data analysis using baseline surveys and weekly interviews.

A literature review was used in developing the questionnaire tools to assess demographics, number of trips, distance, hours, health and income status of rickshaw drivers. The semi-structured weekly interviews allowed study participants to elaborate on personal experiences of driving rickshaws.

II. Literature review

A. Review of rickshaws in Nepal

Research on rickshaws in Nepal is limited. When the electric rickshaw became a popular mode of transport in the Terai region of Nepal in 2015 [10], various newspaper and research journal articles were published elaborating on both the positive and negative impact of electrically assisted and electric rickshaws. Electrically assisted rickshaws and electric rickshaws are considered to be faster than pedal rickshaws, while also reducing physical stress, allowing more trips per day and earning higher income for the drivers [11]. The overall positive impacts focused on employment opportunities, cheaper travel fare and sustainability in transport with an increase in the number of rickshaws in different cities [12]. The challenges that remained were traffic congestion, regulatory barriers and lack of policies affecting the rickshaw drivers and government's inability to outline a proper management plan for electrically assisted and electric rickshaws.

In 2017, a study conducted on the modification of existing pedal rickshaws to electrically assisted rickshaws [13], explored the stability and safety of pedal rickshaws using Direct Current (DC) motor, batteries, differential driving system and a disc braking system. The prototype was leased for over a three-month period, but at a rate double than that of leasing a pedal rickshaw. A Pedal rickshaw is leased at Nepali Rs 100 (USD 0.90[3]) per day, the prototype was leased at Nepali Rs 200 (USD 1.80) per day. However, the rickshaw driver reported an increase in earnings of approximately Nepali Rs 20,000 (USD 179.26) per month using the prototype. Hence, the driver eventually opted to buy the prototype for Nepali Rs 1 lakh (USD 896.40).

An Asian Development Bank (ADB) funded pilot project, in 2017, introduced a pedicab deployed in Kathmandu and Lumbini, Nepal. It was a three-wheeler with a fibre body including an electric assisted system in addition to the pedal driving system. Thirty pedicabs operated for six months in Kathmandu and another thirty were in Lumbini for one and half years. Unfortunately, these pedicabs were not sustainable in the long-run because of

[3] As per Nepal's central bank - Nepal Rastra Bank (on 13/05/2019), USD 1 = 111.56

technical issues such as the electric assisted system working only when the pedal chain completed a full rotation. This was problematic because when brakes are applied while going uphill, it is extremely difficult to complete one rotation in order to start the electric assisted system. Also, different sensors that were used in the pedicab did not work as designed. A Californian- company designed the pedicab and deployed it in Nepal without fully understanding the local context. This made it difficult to address mechanical and electrical challenges as well as regulatory issues.

Without any legal framework or guidance to regulate electric rickshaws and pedicabs, the Kathmandu traffic police confiscated these pedicabs. In Lumbini, the lack of repair and maintenance facilities and spare parts added to the difficulties for pedicab drivers. The drivers in Lumbini eventually started using the ADB pedicabs without the electric assisted system as a regular pedal rickshaw (P. Khanal[4], personal communication, March 25, 2019).

In 1999 Nepal banned diesel powered three wheelers as a result of excessive air pollution. The three wheelers were then modified into battery powered Safa Tempos, which are considered better for the environment. From 1999 to 2000, the number of Safa Tempos in Kathmandu increased from 200 to 600 but environmental concerns over disposal of the lead acid batteries in Safa Tempos led to the GoN banning additional units [11]. Since then, the use of Safa Tempos has not increased due to inconsistent government policy and strong opposition from fossil fuel vehicle interest groups with close ties to the government [11]. The financial interests of conventional transportation entrepreneurs hindered the growth of electric vehicle (EV) technology as the entrepreneurs saw the increase in EVs to be a threat to their businesses. Business groups like these have significant influence on policy making, as the number of EV investors and businesses are few with little experience in dealing with the politics of the transportation industry[5]. The GoN also started giving the same subsidies for fossil fuel vehicles as that for electric vehicles. Although the number of Safa Tempos did not increase, advanced kits and motors of greater power (5 KW) and voltage (72 V) are used along with the introduction and launch of lithium ion batteries (S. Bhandari[6], personal communication, January 9, 2019).

With the introduction of more environmentally driven policies, permission for the operation of electric rickshaws was granted by the Ministry of Physical Infrastructure and Transport in 2014 [10]. Despite these policies promoting electric vehicle use, pedal rickshaws are still widely used. Rickshaw drivers refuse to give up their existing rickshaw as scrap even though it earns the drivers less than electrically assisted and electric vehicles. About 442 people carrier and 200 cargo pedal rickshaws are still in operation in Chitwan, a city in the Terai region of Nepal. However, there are a few challenges related to electric rickshaws:

- Cost: an electric rickshaw can range from Nepali Rs 1.5 lakhs (USD 1,344.60) to four lakhs.
- Mechanical: Limited mileage, power, inability to pull uphill, unreliable battery.
- Geography: Nepal's terrain is different from other South Asian countries. Unlike the flat lands in India and Bangladesh, Nepal has hilly areas and slopes making it difficult for electric rickshaws with limited power and torque capacity to drive uphill. Therefore, there is a rise in the use of petrol and diesel powered auto-rickshaws throughout Nepal [14,15]. In Chitwan, the number of electric rickshaws

[4] Prashant Khanal, Project representative, Improved Pedicab

[5] "Electric Vehicle Technology in Kathmandu, Nepal - Semantic Scholar" https://pdfs.semanticscholar.org/c927/223f16f3f3710bf0b832a3cec785caba8441.pdf. Accessed 13 May. 2019

[6] Sudeep Bhandari, Manager EV department, Eco-visionary Nepal

decreased from 1200 to about 150 after the introduction of fossil fuel powered auto rickshaws, whose number surged to about 900 (D.K. Shrestha7, personal communication, February 10, 2019).

- Practical and economic: Lack of charging stations, intermittent power cuts for self-charge, high cost of changing batteries every six to 12 months and loss of customers due to restrictions of operating on primary roads for high speed vehicles.

Due to these challenges, electric rickshaws are losing popularity in cities such as Chitwan as a result of inconsistent government policy and opposition from interest groups of fossil fuel vehicle owners, who have close ties to the government (D.K. Shrestha[8], personal Communication, February 10, 2019). However, attempts to motorise the pedal rickshaw in Nepal were initiated through personal and institutional efforts (B. Sapkota[9], personal communication, October 15, 2018; B. Paudel[10], personal communication, November 5, 2018). In addition to regulatory challenges, they also faced a number of mechanical challenges (e.g. breaking of shaft, unsafe braking system), legal and policy challenges (e.g. reluctance from various government of Nepal authorities to give permission) and behavioural challenges (e.g. difficulty in building rapport and trust with rickshaw drivers and untimely payments). Such challenges prevented further progress towards modifying pedal rickshaws to electrically assisted rickshaws.

The modification of pedal rickshaws into electrically assisted rickshaws improves performance. In countries such as Bangladesh and India, this reasoning is used to move forward with modification [16]. The limited mileage and air pollution produced in generating thermo-electricity while charging batteries in the earlier versions of modified rickshaws led to new generations of solar powered electrically assisted rickshaws with better mileage and energy conversion efficiency [17,18]. In Bangladesh, around 300,000 rickshaws are electrically assisted and approximately 300,000 rickshaws are solely electric [11]. In India, it is estimated that 1.5 million electric rickshaws are in operation [19]. Similar electric rickshaws, as mentioned earlier, are also operational in the Terai region of Nepal [20].

The review highlights the discourse and challenges for the various types of rickshaws in Nepal, while highlighting opportunities for advancement, particularly in the electrically assisted rickshaw field. The following section provides an overview of the gaps that this research project is aiming to address.

B. Gap analysis

Rickshaws in Nepal are still pedal driven and involve physical labour. The arduous pedalling on the part of drivers is not by choice but rather by compulsion for their sustenance. Even in cases where drivers earn well, there is almost no financial security. The amount of income generated depends on the frequency of trips and the load a rickshaw driver can manage. It requires not just efficient mechanics, but also for the rickshaw driver to be in good health. As such, this study aspires to address the question - can electrically assisted rickshaws have a positive impact on the health and earning capacity of rickshaw drivers in Kathmandu?

[7]Dil Kumar Shrestha, Secretary of Chitwan Rickshaw and Auto-Rickshaw Trade Union

[8] Dil Kumar Shrestha, Secretary of Chitwan Rickshaw and Auto-Rickshaw Trade Union

[9] Bharat Sapkota, Founder, Green World Solar Pvt. Ltd.

[10] Bharat Paudel, Founder, Clean Energy International Pvt. Ltd.

Introducing an improved version of the rickshaw could be a potential solution. Rickshaws operating within Kathmandu typically have a gear ratio of 1.56 between the front (47 tooth) and rear sprockets (30 tooth), which requires above average physical effort for the driver to pull and operate cargo carrying rickshaws. Several attempts [5] and studies to reduce the gear ratio and provide power assistance have been conducted, but drivers still need to pedal with significant physical effort to drive the rickshaw.

The use of batteries is another challenging area. Lead acid batteries are used extensively for electric rickshaws, which need replacement every 6-12 months. This is one of the reasons for the dwindling popularity of the electric rickshaws in some of the cities of Nepal such as Jhapa and Chitwan where petrol powered auto rickshaws have become more popular [21,22]. According to the World Health Organization (2016), lead exposure accounted for 495,550 deaths and 9.3 million disability-adjusted life years (DALYs) lost due to long term impacts on health, with the highest burden in low and middle income countries [23]. The alternative is the use of lithium iron phosphate (LiFePO4) batteries, which last for more than 3-5 years but they are more expensive costing double that of lead acid batteries and are not easily available in Nepal. However, these batteries have higher efficiency, longer lifetimes, faster charging capabilities, and lower incremental cost for energy supplied throughout their lifetime [24]. Moreover, these batteries are less harmful than lead acid batteries [25].

There are other constraints for both electrically assisted and electric rickshaws to consider with regards to cost and limited space in traffic saturated urban cities such as Kathmandu. Therefore, any rickshaw must be designed in a way that is appropriate for Nepal's topography, regardless of price, in order to have traction.

Despite the limitations of both types of rickshaws, electrically assisted rickshaws in comparison to new electric rickshaws are more suitable given the following reasons:

- Modification is made to existing pedal rickshaws, so no new vehicles are introduced. There is no added burden to Kathmandu's growing traffic and conversion reduces waste by improving existing rickshaws.
- Addition of e-kits requires lower initial capital expenditure for rickshaw drivers, compared to new motorised vehicles or electric rickshaws. For example, an electric rickshaw can cost up to Nepali Rs 400,000 (USD 3,585.51), whereas the modification of this study's modification costs Nepali Rs 80,000 (USD 717.10).
- There is the option of switching between electric and pedal functions depending on the Kathmandu terrain such as slopes, allowing for longer use of the batteries.

Based on the above premise the following section focuses on the development of the e-kit used in the modification of pedal rickshaws in this study.

III. Concept generation

The first versions of the rickshaw were hand pulled carriages. In 1929, one of the first recorded attempts at modifying the traditional rickshaw took place, replacing the person pulling the carriage with a cycle system[4]. In more recent years, several attempts to modify the cycle rickshaw using engines, motors, or other power sources have happened in various parts of the world [5]. Nowadays, the basic idea behind modification is to either add some extra power source by removing the pedal driving system with an engine or motor. Else, it

is to add extra power sources with the existing pedal driving system. These are found in countries such as Bangladesh, Pakistan and India, where millions of such modified rickshaws are used.

The concept of the prototype in this study is to modify pedal rickshaws by adding an electrical motor, controller, brakes and batteries to the existing pedal system. The batteries are charged with hydro-electricity which accounts for more than 90% of the total electricity production in Nepal [7]. Moreover, the pedal rickshaw's mechanical system is customised and tested to run efficiently according to the geography of Kathmandu. The modification is done as a simple conversion using common kits and no intellectual property rights required. However, this type of modification is being done for the first time in Nepal.

Electric rickshaws face the problem of being completely dependent on the battery and motor for continuous operation and batteries get drained completely and motor systems have technical issues during travel leaving drivers helpless. In modified rickshaws, the existing pedal system would act as backup in such cases. The modified pedal rickshaw would be powered by both battery and human energy in upslopes which will increase the overall power capacity of the rickshaws while requiring less physical energy from drivers. Also, the rickshaw driver can pedal the rickshaw even if the battery gets drained or technical issues arise in the electric assisted system, which gives confidence to the rickshaw drivers to go for longer trips as opposed to the risk of being stranded.

The concept in this study is to modify rickshaws using an electrical motor, controller and batteries. The e-kits were added to the pedal rickshaws making them a hybrid rickshaw and the batteries were charged using hydro-electricity.

A. The prototype

In the study, the prototype design includes a power transmission system, a motor, braking system and battery. Table 2 provides the list of the e-kit components. The specifications of the system components were configured by calculating the power requirements for carrying people, cargo, road gradient, speed of the vehicle and distance travelled [13]. See Appendix 5 for images of the prototype and parts, and the calculation for the motor.

Table 2: Components of the e-kit

Batteries: lithium ion and lead acid
Controllers: 30 ampere and 38 ampere
Disc brakes: Hydraulic and Rope
Motors/Transmission systems: Shaft Axle (Differential) and Chain Sprocket (Non-differential)
Accessories: horn, lights, key-lock, wires, miniature circuit brake switch (MCB)

Use of differential transmission system decreases the minimum turning radius, increases manoeuvrability facilitates even distribution of tractive force and braking force in both the wheels and gives balance in the modified pedal rickshaw. Hence, priority was given for the motor with shaft axle differential. Deep cycle lead acid batteries and lithium ion batteries

are used to facilitate fast discharge and charge, with priorities given to lithium ion batteries as mentioned in the gap analysis. Disc brakes and different accessories were used to enhance the safety of the modified rickshaws.

Six pedal rickshaws were modified using various combinations of transmission systems (motors), batteries and brakes. All rickshaws included the accessories mentioned in the table above. Table 3 outlines the composition of each pedal rickshaw e-kit.

Table 3: Composition of individual electrically assisted rickshaw

S. No	**Motor (transmission system)**		**Battery**		**Disc Brake**	
	Shaft axle (differential) (800W)	Chain sprocket (nondifferential) (750W)	Lead Acid	Lithium ion	Mechanical	Hydraulic
Rickshaw 1	×			×	×	
Rickshaw 2	×			×	×	
Rickshaw 3	×		×		×	
Rickshaw 4	×		×		×	
Rickshaw 5	×		×		×	
Rickshaw 6		×		×		×

Figure 2 represents the process of modification of the electrically assisted rickshaw. The addition of the e-kits has the potential of increasing the performance and efficiency of existing pedal rickshaws.

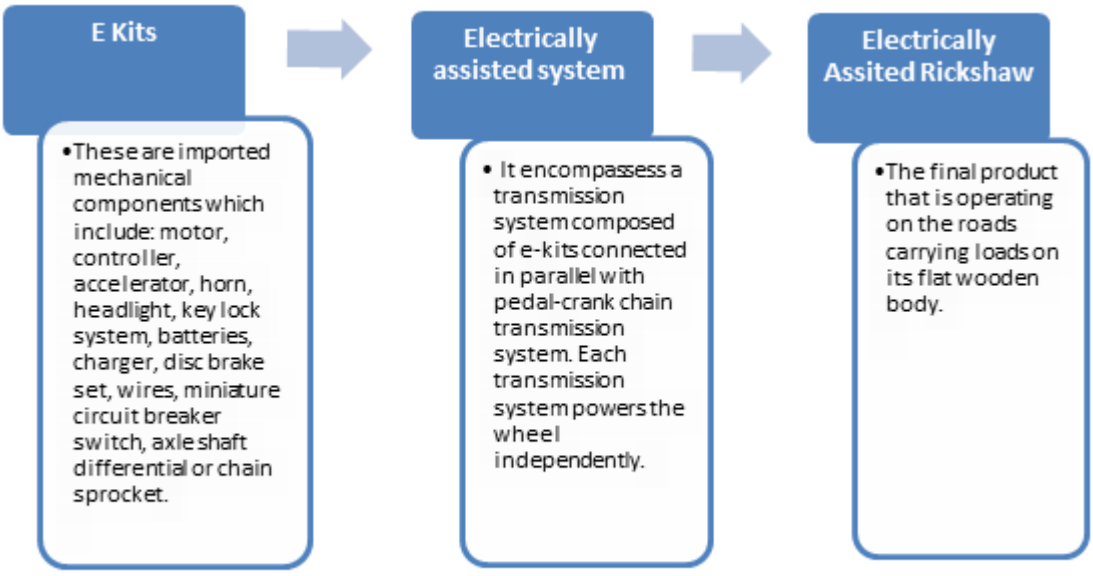

Figure 2: Overview of the electrically assisted rickshaw

In summary, by modifying existing pedal rickshaws, as opposed to introducing new electric rickshaws, the study prototype can potentially keep costs low for drivers. The use of lithium ion batteries and transmission systems increases the performance and efficiency of the pedal rickshaws. Not only would this be a step towards building a clean energy transport system, but it can shift the onus of operating a rickshaw from human labour to electrical energy, helping to improve health status and quality of life for rickshaw drivers.

IV. Research Methodology

This study aims to develop an understanding of electrically assisted rickshaw operation in Kathmandu with the purpose of generating positive impact on the health and earning capacity of rickshaw drivers.

A case study method apart from describing a situation, helps to understand 'how' and 'why' situations occur. This study involves answering the 'how' question mentioned in the gap analysis section. Further complexities can emerge given the variations in viewpoints of interviewees (rickshaw drivers). However, Kane and Brún suggest that case study method allows the researcher to collect and present information in a way that provides more context [26]. They are good for showing how something happens or works in a real life situation. This can be especially valuable in the context of understanding the mechanics and impact of electrically assisted pedal rickshaws in Kathmandu, through interpretations and comparisons of different narratives of the rickshaw drivers.

Case studies can be conducted and written with many different motives, including the simple presentation of individual cases or to arrive at broad generalisations based on case study evidence [9]. Hence, the case study method is appropriate for this study because it is able to provide in-depth explanations of individual cases i.e. rickshaw drivers, from qualitative and quantitative data. Figure 3 below illustrates the research design.

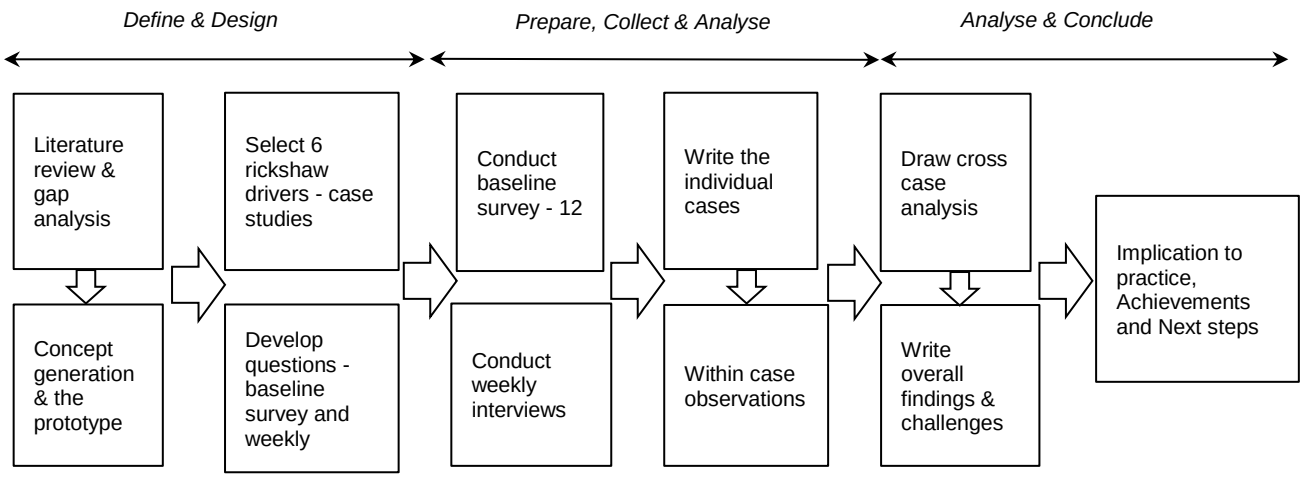

Figure 3: Research Design

A. Data Collection

The data collection was conducted through baseline surveys and weekly semi-structured interviews with the modified pedal rickshaw drivers, which is advantageous to create a robust narrative around modified pedal rickshaw and its use and impact.

1. Baseline survey and weekly interviews

Twelve baseline surveys were carried out prior to the weekly data collection with the six rickshaw drivers (Appendices 1 and 2). The survey was designed to understand the socioeconomic conditions (earning capacity and health) of the rickshaw drivers, and capacity and utility of the pedal rickshaws in operation before using the modified rickshaws. The baseline survey questionnaire was piloted and revised in November 2018 before baseline data collection in March/April 2019.

Drivers of the modified pedal rickshaws were followed for a month with 4 data collection points - weekly interviews. The drivers were visited daily or once in two days for the period of one month to collect data on number and duration of trips, load carried, distance travelled, problems faced and their overall experience with the modified rickshaw.

2. Number of case studies

The objective of the study was to modify 15 rickshaws and test them. However, there were continuous delays from the three suppliers of the various e-kit components (over 2 months), which did not align with the timeline of the study and report. Once all the components arrived, there were unforeseen mechanical issues with modifying the rickshaws, which are elaborated in the challenges section. Furthermore, gaining permission from the municipality and the Department of Transport Management (DoTM) turned out to be time consuming and difficult. As such, six modifications were completed within the timeframe of the study, including the four weekly data collection points. The remaining 9 rickshaws are being modified and tested at the time of writing.

Six rickshaw drivers enrolled in the study, reporting on the impact and benefits of the electrically assisted rickshaws. Analysis of specific indicators (mentioned above) before and after the modification is presented in the following case studies section. The drivers were selected with the help of the Rickshaw Association in Kathmandu, based on drivers' interest to modify their rickshaws, availability and sobriety.

3. Selection of site and permission from authorities

Kathmandu was selected for the study based on the following reasons:

- The original prototype [13] which operated for more than a year created interest among several pedal rickshaw drivers in Kathmandu. They expressed interest in installing the e-kits on their rickshaws.
- Pedal rickshaw drivers who carry cargo earn about Nepali Rs 7,000 - 20,000 (USD 62.74 - USD 179.30) in a week, indicating they can afford the e-kit.
- Good relationship and accessibility to the people and resources of the Rickshaw Association.
- Permission to conduct the feasibility study on 6 pedal rickshaws was obtained from the Tokha municipality (where the rickshaws have been registered), DoTM and Nepal Rickshaw and Cart Workers Union, Kathmandu.
- Rickshaws carrying heavy loads on slopes in Kathmandu faced challenges. Therefore, cargo carrying rickshaw drivers were identified as early adopters of the modified pedal rickshaws.

4. Contract for the rickshaw drivers

A contract document consisting of the agreement and the terms and conditions was outlined in Nepali with the help of a lawyer. It was signed by the rickshaw drivers at the time of enrolment in the study. The contract states that the rickshaw drivers must deposit a specific amount of money to have their rickshaws modified. In exchange, the project bears the repair and maintenance costs (unless the damage is intentional or due to extreme carelessness) for the modified rickshaws during the six month period of use. After the end of first three months, the rickshaw drivers will have the option to return the e-kits and get back the security deposit or pay the remaining amount to purchase and keep the e-kit for their rickshaws.

V. Case studies

A. Rickshaw Driver 1

1. Background

Rickshaw driver 1 is 33 years old and has been driving the rickshaw for 2 years. He is originally from Ramechhap (a district in Eastern Nepal) and lives in Kathmandu in a rented room. He also owns a small tea shop, serving tea to his neighbourhood's vegetable sellers and buyers. On average, he earns approximately Nepali Rs 10,000 (USD 89.63) per week. He usually carries vegetables on his rickshaw. Please refer to Table 3 for the specification of rickshaw driver 1's e-kit.

2. Individual Challenges

As one of his kidneys is damaged, he often suffers from severe pain for which he needs to go to the hospital. Although the doctor prohibits him from carrying heavy loads, he refuses to give up rickshaw driving and carrying heavy loads, as it is his source of livelihood. He regularly takes medicines and spends about Nepali Rs 1,100 (USD 10.00) per week on medicines. He received donations from several organisations for treatment but still prefers to earn on his own and says he does not want to beg while he can still work. For him, the challenges in rickshaw driving are that it is physically taxing and there are unfair rates. His other skills include house wall painting, electrical wiring and spray painting but he prefers rickshaw driving as he believes it has a promising compensation.

3. Observations

Table 4: Data from Rickshaw driver 1

Indicators	Baseline	Week 1	Week 2	Week 3	Week 4
No. of trips (per day)	5	5	5	5	5.5
Distance (km per day)	45	20	19	20	21
Load (kg, avg/max)	400/600	192/350	171/350	217/400	172/400
No. of hours of driving per day	8	2	2	2	2
Income per week in Nepali Rs (USD)	12,000 (107.56)	11,650 (104.42)	11,100 (99.49)	12,150 (108.91)	12,900 (115.63)

In the baseline survey the rickshaw driver reported the number of trips, distance travelled and the load carried, based on his experience of driving the rickshaw over the last few years. During the weekly data collection, it was found that he was doing shorter trips carrying smaller loads as compared to the baseline survey, given the arbitrary nature of the demands from customers. However, he was driving the rickshaw for 2 hours/day on average after the modification in comparison to 8 hours/day (before), for nearly the same number of trips and half the distance travelled. Due to the fact that several drivers reported lighter loads and fewer/shorter trips after conversion, self-reported data collected at baseline may have been over-estimated averages, whereas the weekly follow-up data was more accurate.

After driving the modified rickshaw, the physical stress on his body reduced significantly. He said that he experienced fewer outbursts of pain. He is now able to follow the doctor's medical advice.

B. Rickshaw Driver 2

1. Background

Rickshaw driver 2 is 23 years old and driving his rickshaw for the past five years. He is the head of the Rickshaw Association of Kathmandu. He carries metal structures from hardware stores to nearby places and earns about Nepali Rs 13,000 (USD 116.52) per week on average. See Table 3 for the specification of rickshaw driver 2's e-kit.

2. Individual challenges

Driver 2 got married at an early age and has a child. He aspires to provide good support to his wife and education for his child. He is supporting his family of three members who depend solely on the income generated from his rickshaw driving. Having a small physique, he finds rickshaw driving to be a physical challenge.

3. Observations

Table 5: Data from rickshaw driver 2

Indicators	Baseline	Week 1	Week 2	Week 3	Week 4
No. of trips per day)	5	5	5	5	6
Distance (km) per day)	25	40	30	30.5	35
Load (kg, avg/max)	225/300	87/250	98/300	88/300	100/250
No. of hours of driving per day	4	2	2	2	2.3
Income per week in Nepali Rs (USD)	13,200 (118.32)	14,800 (132.66)	13,150 (117.87)	11,400 (102.18)	16,750 (150.14)

He is very happy after the conversion as he can easily carry loads without much physical labour. He can complete more trips than before and is earning well. At the end of the day he does not feel tired like before. He was initially disappointed as it took time for the e-kit installation because he was the first one to have it installed. But after it was done, he was happy with the modification. He helped in installing e-kits in other pedal rickshaws and facilitated receiving permission from the authorities to conduct the study. He is collaborating with the team to develop a business model.

C. Rickshaw Driver 3

1. Background

Rickshaw driver 3 is 47 years old and returned from Malaysia five years ago when he started driving a rickshaw. He has two sons, whom he financially supported in the completion of their engineering degrees. On average he earns approximately Nepali Rs 10,000 (USD 89.64) per week. He is working in an area that has upslopes. See Table 3 for the specification of rickshaw driver 3's e-kit.

2. Individual challenges

Driver 3 suffered a back injury while he was in Qatar resulting in sudden and frequent acute back pain. Pulling the rickshaw affects his back, so he often takes breaks while driving the rickshaw.

3. Observations

Table 6: Data from rickshaw driver 3

Indicators	Baseline	Week 1	Week 2	Week 3	Week 4
No. of trips per day	5	5	5	4	5
Distance (km) per day	35	21	22.5	18.5	18
Load (kg, avg/max)	150/300	85/300	97/300	113/400	48/150
No. of hours of driving per day	3.5	2.75	2.5	1.75	2
Income per week in Nepali Rs (USD)	10,000 (89.63)	11,150 (99.94)	8,900 (79.77)	7,550 (67.67)	8,100 (72.60)

Prior to the modification, he had to climb down the rickshaw seat to carry the load, one hand at the handle and the other to pull the rickshaw, which was very exhausting. Now he can easily carry loads uphill without having to get off his seat. He feels less tired and healthier now and is satisfied with the money he makes with less effort. The only problem he faces is the brakes not working properly while going downhill with a load.

D. Rickshaw Driver 4

1. Background

Rickshaw driver 4 is 49 years old and has been driving the rickshaw for more than 16 years. He owns a small factory that manufactures concrete rings. He only charges for the rings and delivers them for free. He also owns a mini truck for carrying the rings but he still favours driving the rickshaw for personal reasons such as carrying his children to school. See Table 3 for the specification of rickshaw driver 4's e-kit.

2. Individual challenges

Driver 4 finds rickshaw driving physically tiring though he says that it is in a way essential to keep him healthy and fit. He raises two families (one in his village and one in Kathmandu) with five children pursuing secondary and higher education in different places. He constantly feels the financial burden as he has to support his children's education and provide for two families.

3. Observations

Table 7: Data from rickshaw driver 4

Indicators	Baseline	Week 1	Week 2	Week 3	Week 4
No. of trips per day	8	3	4	3	3
Distance (km) per day	50	53	50	40	50
Load (kg, avg/max)	300/600	150/250	123.5/250	143/300	133/250
No. of hours of driving per day	5	2.75	3.15	2.14	3
Income per week in Nepali Rs (USD)	10,000 (89.63)	4,550 (40.78)	8,500 (76.19)	5,100 (45.71)	5,250 (47.05)

The modification was advantageous for him because now he does not have to drive his mini truck for lighter loads. In the baseline survey, the various data he reported is the average for the last few years. Nowadays, he has left working with other suppliers because he wants to focus on his business, as such he carries only the concrete rings and the associated machineries for digging wells for his business. This has allowed him to focus more on building his own business rather than working for other suppliers. Hence, the number of trips has decreased from 8 per day in baseline survey to 3 per day after the modification.

E. Rickshaw Driver 5

1. Background

Rickshaw driver 5 is 35 years old and has been driving the rickshaw for more than 16 years. He is originally from eastern Nepal but lives temporarily with his family of three in Kathmandu. On average, he earns approximately Nepali Rs 8,000 per week by driving the rickshaw. See Table 3 for the specification of rickshaw driver 5's e-kit.

2. Individual challenges

Driver 5 suffers from intermittent hydrocele, which is a type of swelling in the scrotum, and high blood pressure, for which he is on medication. Besides this, he provides for a family of two in Kathmandu which imposes economic challenges on him to save money.

3. Observations

Table 8: Data from rickshaw driver 5

Indicators	Baseline	Week 1	Week 2	Week 3	Week 4
No. of trips per day	5	3	4	4	4
Distance (km) per day	30	24	26	45	24
Load (kg, avg/max)	250/500	45/80	38/70	53/150	56/200
No. of hours of driving per day	4	1.5	1.5	1.5	1.6
Income per week in Nepali Rs (USD)	8,000 (71.71)	6,300 (56.471)	6,800 (60.95)	10,850 (97.25)	7,050 (63.194)

With the modified rickshaw his self- esteem has increased. He can go for longer trips, which he was not able to do before the modification. He reports generating additional income through activities such as loading and unloading of goods in his leisure time.

F. Rickshaw Driver 6

1. Background

Rickshaw driver 6 is 46 years and has been driving a rickshaw for 20 years. He has a son who earns enough to support the family. He is now driving the rickshaw to save some money for the future. He carries lighter loads and only does a few trips per day. See Table 3 for the specification of rickshaw driver 6's e-kit.

2. Individual challenges

Driver 6 feels physically exhausted while driving the rickshaw as he drives frequently through upslopes. He initially said that he drank because of tiredness. He also felt it was the reason for frequent quarrels in his family.

3. Observations

Table 9: Data from rickshaw driver 6

Indicators	Baseline	Week 1	Week 2	Week 3	Week 4
No. of trips per day	4	3	3	4	3
Distance (km) per day	20	16	15	20	14
Load (kg, avg/max)	80/200	58/125	38/70	60/150	57/120
No. of hours of driving per day	4.5	1.5	1.25	2.25	1.5
Income per week in Nepali Rs (USD)	6,000 (53.78)	6,550 (58.71)	5,400 (48.40)	8,700 (77.98)	6,600 (59.16)

Due to his old age and grown up son, he does not need to work very hard to make money. However, he now drives the modified rickshaw to save and to spend some money on himself. As such, the converted rickshaw is quite helpful for him.

VI. Findings and Discussion

Findings from the baseline survey and weekly data collection with rickshaw drivers show that although actual income did not increase with use of modified rickshaws, there were improvements in health outcomes and factors that directly affect income earning potential.

Rickshaw drivers reported an estimated average weekly income of Nepali Rs 9,866 (USD 88.44) during the baseline survey. After the fourth week of modification, the average income earned by drivers was Nepali Rs 9,218 (USD 82.63) per week. Although income did not increase for the drivers after modification, researchers do anticipate an increase in weekly earnings over the next few months. The data not only indicates improvements in health behaviours of the drivers, but also a decrease in both the duration and physical strain per trip. The rickshaw drivers themselves are optimistic about increasing the number of customers they serve and the income they earn. This is likely a result of the reduced fatigue and surplus leisure time they are experiencing since modification of the rickshaw. Further research will highlight if rickshaw drivers are able to increase the number of customers or if they engage in other forms of income generating activities due to the time saved from driving rickshaws.

Similarly, while the number of trips per day went down from five trips a day to four trips after modification, number of trips per day is also expected to increase steadily as drivers become more comfortable with the modified rickshaw. The rickshaws are charged during the night for about 8-10 hrs at off-site workshops, as they are not in operation. The auto-cut system in the charger cuts the line once the battery is fully charged. The distance that can be covered on full charge is about 65 km on average, which is higher than the distance travelled by each modified rickshaw (case studies section). Hence, charge time is not a limiting factor

to the number of trips, except in case of power cuts and charger problems which were not reported during this study period.

The number of trips per day is dependent primarily on demand from customers. These are suppliers and wholesalers who require cargo carriers for movement of goods within Kathmandu. Their demand tends to be sporadic and concentrated during festival seasons like Dashain and Tihar (October and November). Additionally, demand for cargo rickshaws also tend to be low during Monsoon season and to a lesser extent during Summer.

Of further significance is the data indicating a nearly 50% reduction in average time to complete trips of the same distance (4.67 hrs per day on average before modification, to 2.03 hrs per day on average after modification). Quicker trips can allow drivers to work with more customers, or be involved in other income generating activities such as loading and unloading supplies for their current customers.

The level of physical stress decreased for almost all the rickshaw drivers after modification. Before modification drivers rated physical stress at 7 out of 10. After modification, the drivers rated physical stress as 2 out of 10. Typically, pedal rickshaw drivers require rest breaks after five to 10 trips due to exhaustion. Most of the drivers drink alcohol to relieve their physical exhaustion. After modification, drivers reported minimal physical exertion, only pedalling if their battery drained to zero or if there was a problem with the modified rickshaw system. Moreover, drivers felt more physically ready for the next trip. This was not the case before the electrically assisted rickshaw system.

The drivers also experienced improvements in their self-esteem. They feel proud operating the electrically assisted rickshaw. The introduction of this new technology is also changing their customers' perception towards the rickshaw drivers. Their work is being viewed as more dignified and bringing respect to the profession. With further advancements in traditional rickshaws, both drivers and their customers (wholesalers and suppliers) believe rickshaw driving will be seen as a lucrative profession, offering employment opportunities for more people (drivers and customers, personal communications, March 29 - April 15, 2019 [11]). As observed from the six case studies in the previous section, four rickshaw drivers have increased their earnings and all drivers have demonstrated increase in earning potential with reduced physical stress.

The study data also indicated a nearly 50% reduction in both amount of alcohol and number of cigarettes consumed in a day. However, there was no significant reduction in the body pain of the rickshaw drivers. Because the modified rickshaw doesn't have a proper suspension system, the driver's body absorbs the shock that results from driving on rough roads at higher speeds. This was the main reason for the continued body pain, despite modification. Still, the rickshaw drivers did report much higher levels of physical exertion in driving pedal rickshaws in comparison to driving the electrically assisted rickshaw.

In this study, three of the conversions were with lead acid batteries and three were lithium ion batteries. A fully charged lithium ion battery rickshaw can complete a two-way trip totalling up to 70 km, while carrying a load one-way of a trip. Lead acid batteries can complete up to 55 km. The addition of e-kits with the differential system, lead acid batteries, a waterproof box for batteries and other structures increases the weight of a rickshaw by about 52kg, making the total gross weight about 90kg. E-kits with lithium ion batteries on the

[11] Six rickshaw drivers of this study and their customers

other hand, add 34kg to the rickshaw, bringing the gross weight to around 72kg. This suggests that lithium ion batteries add less weight to the rickshaws, and therefore result in better mileage. Further details on the operating profile of each driver can be found at: https://docs.google.com/spreadsheets/d/160xFWxOdEVky8ksT6Spb_WffMeQTN5RQw4Z_19aw0c4/edit?usp=sharing

Figure 4 below outlines the supply chain with different stakeholders responsible for the import process of materials in this study. Stakeholders identified during the import process were given money and information for the import of e-kits. Manufacturers or suppliers were contacted through online platforms like Alibaba, We Chat, e-mail or by visiting the company in person. The specifications of the required e-kits were given to the manufacturer. Orders were placed through the import company if the manufacturer was able to produce the e-kits of given specification and supply them at a reasonable price. This was an iterative process until a suitable manufacturer or supplier was found. Payments were made to the import company through telegraphic transfer.

Figure 4: Supply network

VII. Challenges

The challenges of the study can be broadly categorised into 4 specific themes: i) mechanical challenges ii) behavioural challenges iii) policy challenges and iv) supply chain challenges.

A. Mechanical Challenges

The team faced a number of mechanical challenges both during modification of the pedal rickshaw and with repairs and maintenance once the vehicle was in operation on the roads of Kathmandu.

The pedal rickshaw dimensions were non-standard and varied in size. For instance, the chassis length varied from 75cm-82cm because they were locally manufactured at different workshops. The chassis was reforged to 75cm in order to standardise it for modification. Accompanying parts such as the wooden frame holder, bearing holder, chassis support also had to be refitted to the newly sized chassis by the process of forging, drilling and welding.

Despite being given clear load carrying guidelines, many repair and maintenance issues were due to overloading; at times carrying up to 400kg up slopes. This was further compounded by the unpaved roads and potholes. In fact, the original shaft of the rickshaws broke a number of times.

A new mild steel shaft was prepared for rickshaw models without a differential system. Original wheel spokes were replaced with thicker ones for safety reasons. To manage the heavier loads 8mm square rods were welded between the rim and central hub replacing the

original 4mm ones. A whole new hub made out of thick iron rods was fitted in the lathe machine. The wheels were re-welded to the newly formed hub. New rims were welded to prevent the wheels from buckling in, which would have compromised the stability of the vehicle. Although the additional expense to the modification cost (Nepali Rs 80,000, USD 717.10) was approximately Nepali Rs 4,000 (USD 36.00), it provided greater strength and durability to the associated parts. As such, it made sense to incur this additional cost for better performance of the modified rickshaw.

Other mechanical issues resulted from a lack of harmony between the existing pedal rickshaw components and the newly added electrical motor system. Problem solving this required innovative thinking. Pedal rickshaw systems had to be redesigned to withstand the potential wear and tear resulting from the increase in power and speed from the motor current while still maintaining stability, absorbing shocks via a proper suspension system, and preventing overheating of wires. The curved and narrow handles of the pedal rickshaws were redesigned into ergonomic handles by cutting and welding straight pipes to better control the throttle mounted.

B. Behavioural Challenges

Although the rickshaw drivers were interested in driving an electrically-assisted rickshaw, there was hesitation in giving up their pedal rickshaw for modification. The modification process was too long for them to go without working typically taking about 3 to 5 days. The only recourse to persuade them to follow through with modification was by agreeing to offer free repairs and maintenance for the first 6 months. The team also had to agree to drivers returning the kits and getting their security deposit back, in the case they did not like their modified rickshaws.

The rickshaw drivers were also reluctant to come to an agreement in the form of a contract signing. Multiple meetings were held to formalise an agreement to manage expectations and outline each party's responsibilities. There was also great difficulty in collecting the security deposit, which was about 20% of the total material cost, even though they initially agreed to deposit that sum.

Rickshaw drivers often became irritated and angered because of the mechanical challenges that came up during modification. Outbursts of anger were mostly due to the delays and two even decided to uninstall the kits. The remaining were persuaded through different types of incentives such as offering snacks and tea and arranging provisions for another rickshaw during modification.

C. Policy Challenges

There are policies which ban the operation of cargo carrying rickshaws, yet lack of enforcement has meant many such rickshaws are still operational in Kathmandu. There have been cases of traffic police confiscating the rickshaws driven on the roads. Those who can apply political influence get their rickshaws released, whereas others lose their rickshaw. This has been the trend in Kathmandu over the past few years. (Ref: Interview with the District head of Nepal Rickshaw and Cart Workers Union Kathmandu).

Similarly, although it is illegal to modify existing vehicles in Nepal, there are not any specific laws or guidelines for the case of improving the performance of vehicles like rickshaws. This loophole allowed the study to move forward with the modification. The team was also aware of the ongoing court case filed against the group that had introduced the design of a pedicab

as described in the background section. These pedicabs were impounded by the traffic police after being stopped in traffic a few years ago. However, given that the modifications were being done for research purposes only and involved a small number of pedal rickshaws, GoN officials indicated through informal conversations that the researchers can go ahead with the project. Nevertheless, they continued to refuse to provide any form of written or explicit permission.

Throughout the feasibility study period, the research team was still liable if a traffic police stopped them or if the electrically-assisted rickshaw was involved in a road traffic accident. So there was a fear that the research team might get sued for the change made in the rickshaws. Because there was very little to no cooperation from the government the research team worked on getting the rickshaw association on board instead, since the association has more political pull with municipality governments.

Although there was significant reluctance in giving formal permits from the ward and municipal offices and Department of Transport Management, the team was able to get 6 modifications completed. The rickshaw association was of great help in navigating the internal politics and bureaucracies of this process. Though, the written permission was still not obtained, verbal permission to conduct the research was obtained after several attempts and petitions.

D. Supply Chain Challenges

The cost of manufacturing a small batch of e-kits including motor, controller, bearings and batteries in Nepal was too costly. The researchers decided it would be more efficient to import the components from China and assemble locally instead. The team contacted Chinese kit manufacturers and suppliers through online social media platform ‘wechat’, after researching the specifications of the kits on different websites such as Alibaba. The team reached out to a number of suppliers, some of whom did not follow through midway. The researchers had to go through a few rounds of reaching out before a suitable supplier was identified.

The import process was also delayed by longer than anticipated. Despite having built in cushion time of 2-3 weeks in the project timeline, it took an extra 2 months than planned. The reasons given by the import agents was that the train and truck carrying the freight were stuck because of snowfall and then later due to the Chinese New Year holiday.

The manufacturers required payment in full before they started manufacturing. 20 lithium ion batteries were ordered but the agent sent only 18 batteries stating that two batteries were rejected during the performance testing. Even though the payment including tax and custom duty was made for 20 batteries, only 18 batteries were received. The team is looking into seeking legal action to claim the remaining 2 batteries. Also, 2A lithium ion charger were delivered instead of the 5A lithium ion chargers as ordered. Since the delivery process was already too lengthy, the team had no other option but to accept the 2A lithium ion chargers. The import agency has given assurance to deliver the remaining 2 batteries during the next import shipment.

Another issue was the physical damage of the kits and batteries which occurred due to improper handling between the border of China to Kathmandu. However, claiming insurance for damaged imports is also a difficult and lengthy process. Claiming insurance is also complicated since the manufacturer only insures goods from when they leave the

manufacturer till when they arrive to the Nepal border. It is null and void once the goods enter the destination country.

VIII. Conclusion

A. Implications to Practice

1. Industry

The concept of electrically assisted rickshaws involves the addition of motorised electrical systems to an existing pedal rickshaw. An electric assist system was selected because of the low operation cost (few units of charge), zero emission during operation, small capital and promising rate of return on investment. Modified vehicles have drawbacks such as heavy weight, lower flexibility, and performance degradation in comparison to purposely built electric vehicles [27]. However, it can provide economic benefits for the operation of electric vehicles by reducing the initial capital expenditure. Fossil fuel vehicles are prohibited in Kathmandu when they reach 20 years of use. The installation of the electric driving system would exempt the vehicle with good structural integrity from being thrown away as scrap or moved out of Kathmandu.

2. Policy

Rules and regulations in Nepal ban any changes in existing vehicles. But, when the modification is being done to increase the performance of the vehicle (rickshaw or old fossil fuel vehicle), there needs to be policy of encouraging such activities. This report shows the benefits of using electrically assisted rickshaws over pedal driven rickshaws. It can be a basis for drafting new policies related to the modification of the pedal driven rickshaws.

More than 2000 pedal rickshaws operate in Kathmandu but there is no government policy for upgrading them. Modified pedal rickshaws could generate interest among rickshaw drivers, whose voices will be crucial in formulating new rules and policies about modified rickshaws. However, GoN made laws to ban rickshaws in Kathmandu because of the slow speed, poor performance, behavioural challenges of rickshaw drivers and rickshaws being inconsistent with the image of the modern city (interviews with the rickshaw drivers). The report demonstrates the benefits of modified rickshaws, which can be a reference for the policy makers making decisions regarding the future of electrically assisted rickshaws.

B. Achievements

The conversion of 10 rickshaws (till the date of April 25) and its benefit over the life of those 10 rickshaw drivers piqued the interest of other rickshaw drivers of Kathmandu. Several calls are received each day from the rickshaw drivers asking about the modification process. The overall analysis of data collected shows that the e-kits can be improved in several ways. The motor capacity of above 1000 W is favourable for the rickshaws as they are more likely to drive in the region that consists of uphill slopes. The disc brake needs to be improved to Anti-lock Braking System to make it more reliable. The number of teeth in the rear sprocket (22 tooth in the differential shaft) should be increased as it makes the pedalling more difficult since the present gear ratio is 2.13. Also turning radius increased significantly as the sprocket is fixed to one of the axles of differential. This is improved by using a sprocket attached to the ring gear of the differential for the pedal driving system or designing suitable transmission system.

The wires in the controller needs to be replaced with high ampere wires (>50A) to address the problem of burns in the connector. The connector should be tightened in the bolts by nuts with lock system. Use of lithium ion batteries demonstrated promising benefits with reduced weight, more mileage, more efficiency. Hence, all the pedal driven rickshaws operating in Kathmandu Valley can be modified with the motor kits, brake and batteries.

The feasibility study of the six modified rickshaws reflected an overall improvement in the operating experience of the drivers. This includes a significant reduction in physical exertion and an improvement in the earning potential of the drivers (explained through the case studies). Based on the positive experiences of the six rickshaw drivers, the Rickshaw Association of Kathmandu was eager to convert the remainder of the 15 pedal rickshaws and work on a business proposal.

A business plan was developed for the modification process. In this plan, 100 e-kits and batteries will be imported from China identifying a reliable and cost-effective supply chain, other parts will be locally manufactured in the workshop. Currently the team is developing a business plan with the Rickshaw Association that involves sourcing the mechanical components, assembling the e-kits and modifying 100 pedal rickshaws in Kathmandu. This business proposal was initiated by the Rickshaw Association. In the proposal put forward, the Association would like the team to co-invest to register a business, source the mechanical parts and modify the pedal rickshaws. The initial capital investment required to move this proposal forward would be approximately Nepali Rs 70 lakhs (USD 62,746.50). Table 10 below shows the tentative cost structure.

Table 10: Cost structure for the business proposal

S.no.	Particulars	Quantity	Unit price (Nepali Rs)	Total amount (Nepali Rs)
1.	1050 W motor kits	100	18,000 (USD 161.35[12])	1,800,000 (USD 16,134.82)
2.	30 Ah lithium ion batteries with charger	100	45,000 (USD 403.37)	4,500,000 (USD 40,337.04)
3.	Miscellaneous (miniature circuit break, wires, rim, shafts, nuts and bolts, etc)	100	7,000 (USD 62.75)	700,000 (USD 6,274.65)
4.	Workshop charges (labour and facility use)	100	5,000 (USD 44.82)	500,000 (USD 4,481.90)

The selling price for one modified pedal rickshaw will be Nepali Rs 1 lakh - 1.2 lakhs (USD 896.38 - 1,075.65). This price includes the cost of modification (Nepali Rs 75,000, USD 672.30), six months free servicing, six months warranty on motor, one year warranty on battery and a margin of 10%. The modified rickshaw will be handed to drivers after 40-50% initial deposit and remaining sum will be collected in instalments of six months to a year. An executive committee is formed and the business will be commencing in the coming months granted there are no accidents and all safety concerns have been addressed through the 15 initial conversions.

[12] As per Nepal's central bank - Nepal Rastra Bank (on 13/05/2019), USD 1 = 111.56

C. Next Steps

Changes will be made on the design of the modified pedal rickshaws in the coming months. This will be an iterative process in which improvements will be done till product stability is obtained. Route demarcation will be done for the safety of the modified rickshaw drivers. They are currently prohibited to operate on the route having large gradient (>10 degree) and on the primary road for high speed vehicles. Changes will be made in the future models to incorporate solutions to these limitations.

Efforts will be made for the legal registration of the modified rickshaws by the Nepal Rickshaw and Cart Workers Union, Ward offices and different political leaders concerned with the socioeconomic conditions of the rickshaw drivers. Provisions for insurance (in case of loss, damage or accident) and driving license will be made for all the drivers of modified rickshaws.

The results of Environmental Performance Index (EPI) mentioned that Nepal's air quality is worst among the 180 surveyed countries [28]. Nepal imports fossil fuels worth of 1.8 billion (2017/2018) [29], whereas Nepal's hydro-electricity potential is about 45000 MW [29], out of which about 1000 MW is being currently produced [7]. GoN is planning to produce 3000 MW within next 5-7 years [7], which demonstrates Nepal's future in electric vehicles charging from self-produced hydro-electricity. Nationally Determined Contribution (NDC) for Nepal shows that by 2050, Nepal will decrease its dependence on fossil fuel in the transport sector by 50% through mass public transport, while promoting energy efficient and electric vehicles. Nepal will develop its electrical (hydro-powered) rail network by 2040 to support mass transportation of goods and public commuting [30]. Considering these facts, electrically assisted rickshaws, although will not able to bring radical change in the national transportation system, will contribute in Nepal's goal to develop electric vehicles.

Clean energy mass transportation needs to be given priority as stated in NDC. However, till it's realised, the smaller vehicles such as electrically assisted rickshaw and electric rickshaw can serve the community to provide benefits to the rickshaw drivers, customers (rickshaws are cheaper, safer and faster) without causing harm to the environment.

The low cost modification of pedal rickshaws into electrically assisted rickshaws impacts on reduced physical strain and health problems, increase in number of trips, shorter duration of the trips, leisure time for family. These collectively have a positive impact on the driver's income earning capacity and health and well-being. However, the product should be made more stable by incorporating new changes for the consistent efficient operation otherwise the issues of repair and maintenance would add the economic burden on the rickshaw drivers.

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Appendices

Appendix 1: Baseline Survey Questionnaires

BACKGROUND
1.What is your name? तपाईंको नाम के हो?
2.What is your age? तपाईंको उमेर कती भयो?
3.What is your address in detail? तपाईंको पुरा ठेगाना बिस्तारमा भन्नुस्?
4.What is your telephone number? तपाईंको टेलिफोन नम्बर कती हो?
5.Please provide the name and telephone number of at least 2 family members specifying your relation. कृपया तपाईंको घरपरिबार का कुनै २ सदस्यको नाम र फोन नम्बर दिनुस ?
6.How many family members do you have? घरमा कती जना सदस्य हुनुन्छ?
WORK EXPERIENCE & SKILLS
7.How many years have you been driving the rickshaw? कती बर्ष देखी रिक्सा चलाई राख्नु भाको छ?
8.What other skills do you have apart from driving the rickshaw? तपाईंमा रिक्सा चलाऊने बहेक अन्न्य कुनै सीपहरु छन? कृपया बिस्तारमा बताउनुस।
SOCIO-ECONOMIC STATUS
9.How much do you earn in a typical week from pedalling your rickshaw? रिक्सा चलाएर सामान्य १ हप्तामा कती पैसा कमाउनु हुन्छ?
10.How much earnings are you able to save in a typical week? कुनै सामान्य १ हप्तामा कती पैसा बचत गर्नुहुन्छ?
11.What is your monthly repair and maintenance cost for the rickshaw? कुनै सामान्य १ महिनामा रिक्सा मर्मत सम्भार गर्दा कती खर्च लाग्छ?
12.What type of maintenance do you require for your rickshaw normally? कुनै सामान्य १ महिनामा कस्तो कस्तो मर्मत गर्नु हुन्छ?
13.Are there other sources of income in your family? If yes, explain in detail. परिवारमा अन्य कुनै आय आम्दनी को स्रोत छ? यदी छ भने बिस्तारमा बताउनुस।
TYPICAL WORKLOAD
14.Typically, what time do you start driving your rickshaw? सामान्यतया कती बजे रिक्सा चलाऊन सुरु गर्नुहुन्छ?
15.What is the approximate number of hours in a day that you drive your rickshaw? सामान्यतया १ दिनमा मोटामोटी कती घण्टा रिक्सा चलाऊनु हुन्छ?
16.What time of the day do you end driving your rickshaw? सामान्यतया कती बजे रिक्सा चलाऊन छोड्नु हुन्छ?
17.How many trips do you make with this rickshaw on a typical/normal day? सामान्यतया १ दिनमा कती ट्रिप /लट रिक्सा चलाऊनु हुन्छ?

18.What is the total distance you pedal (in km) your rickshaw on a typical/normal day? सामान्यतया १ दिनमा कती दुरी (किमी) रिक्सा चलाऊनु हुन्छ?
19.What is the maximum distance (in km) you have been able to travel with a typical load? आज सम्म १ दिनमा सबै भन्दा बढी कती दुरी रिक्सा चलाऊनु भाको छ?
20.How much load (in kg) do you carry on average/normally during a trip? सामान्यता रिक्सा चलाऊदा कती भार बोक्नु हुन्छ?
21.What is the maximum load (in kg) you have carried on your rickshaw? आज सम्म सबै भन्दा बढी कती भार बोक्नु भाको छ?
PERCEPTION OF RICKSHAW DRIVING - technical aspects
22.On a scale of 1 to 10, how physically strenuous would you rate rickshaw driving? १ देखी १० सम्म को स्केल मा तपाईले रिक्सा चलाऊनुलाई शरीरइक तनाब को हिसाबमा कती नम्बर दिनुहुन्छ? १= एकदम आनन्द पूर्ण, १०= एकदम गाह्रो
23.Which features of operating a rickshaw do you find most difficult? रिक्सा चलाऊनुको कुन पक्ष तपाईंलाई सबै भन्दा गाह्रो लाग्छ?
24.Overall, what is the most difficult aspects of rickshaw driving for you? (any 2) रिक्सा चलाऊदा गाह्रो लाग्ने पक्ष कुन कुन हुन?
HEALTH STATUS
25.Do you have any health related issues? If yes, describe each symptom. तपाईंलाई कुनै स्वास्थ्य समस्या छ? यदी छ भने कस्तो कस्तो लक्ष्यण देखा पर्छ?
26.How frequently do you have these symptoms? कती कती समयमा लक्ष्यण हरु देख पर्छ?
27.Are there any medicines you are taking on daily/weekly basis? (list the medicines and the frequency in which they are taken). तपाईंले दैनिक या साप्ताहिक रुपमा कुनै औषधी लिने गर्नु भएको छ?
28.How much do you spend every week on medicines? तपाईंले साप्ताहिक रुपमा औषधीमा कती पैसा खर्च गर्नु हुन्छ?
29.On a scale of 1-10, how healthy do you currently feel? 1= very tired and sick all the time, 10= excellent health १ देखी १० सम्म को स्केलमा तपाई अहिले कतिको स्वस्थ अनुभव गर्नु हुन्छ? १= जतिबेला पनि थकित र बिमार, १०= अती स्वस्थ।
30.How many times did you feel you needed to visit a doctor due to your health condition in the past 1 month? आफ्नो स्वास्थ्य को कारण ले तपाईंले गएको महिनामा कतिपटक डाक्टरलाई भेट्न खोज्नु भएको थियो?
31.How many alcoholic drinks do you have on a typical day? (Amount in litter) तपाईंले १ दिनमा कती मदिरा सेबन गर्नु हुन्छ? (मात्रा लिटरमा)
32.In a day, how much do you spend drinking alcohol? (Nrs) मदिरा सेबन मा दैनिक कती पैसा खर्च गर्नु हुन्छ?

33.How much tobacco do you consume on a typical day? १ दिनमा कती सुर्ती सेवन गर्नु हुन्छ? (मात्रा पटक)
34.How many cigarettes do you smoke on a typical day? १ दिनमा कतिओटा चुरोट सेवन गर्नु हुन्छ?
35.On a scale of 1-10, what is your current level of stress or tension (about anything- finances, health, family, food, kids education, future, housing, etc.) 1= no stress in life, 10= very stressful every day १ देखी १० सम्म को स्केल मा तपाईंले आफ्नो तनाब र चिन्ता लाई कती नम्बर दिनुहुन्छ? तनाब जुन बिषयमा पनि- आर्थिक, स्वास्थ्य, परिवार, बच्चाको पढाई, भबिस्य, घर)
OTHER CONCERNS FOR RICKSHAW DRIVERS
36.Have you ever thought of leaving your current profession? (if yes), why? तपाईंले भबिस्यमा आफ्नो पेसा परिवर्तन गर्ने सोच्नु भएको छ? यदी छ भने किन?
37.What occupation have you thought of switching to if you were to leave your current job? तपाईं अहिलेको पेसा छोडेर कुन पेसामा जने सोच्नु भएको छ?
38.Where do you see yourself in the future? तपाईंले आफुलाई भबिस्यमा कहाँ देख्नु हुन्छ?
39.Where do you see your children in the future? तपाईंले आफ्नो बच्चालाई भबिस्यमा कहाँ देख्नु हुन्छ?
40.Have you experienced and/or witnessed any accidents related to driving the rickshaw? तपाईंले रिक्सा सम्बन्धी कुनै दुर्घटना देख्नु \ अनुभव गर्नु भएको छ?
41.What was the reason for the accident? दुर्घटनाको कारण के थियो?
42.On a scale of 1-10, how safe do you feel driving a rickshaw? १ देखी १० सम्म को स्केलमा तपाईंले रिक्सा चलाऊदा कतिको सुरक्षित अनुभव गर्नु हुन्छ?
43.How reliable is the available braking system? अहिलेको ब्रेक कतिको भरपर्दो छ?
How safe is the rickshaw driving? Are you able to balance and control it easily? रिक्सा चलाऊनु कतिको सुरक्षित छ? तपाईंले रिक्सालाई कतिको सजिलो तरिकाले सन्तुलन र कन्ट्रोल गर्न सक्नु हुन्छ?
44.How much do you rate for the difficulty of load you carry on the back on the scale of 1-10? 1= indifferent about it, 10= most difficult aspect of driving rickshaw तपाईंले १-१० सम्म अंक दिदा कुनै सामान्य ट्रिपमा बोक्ने भरी लाई कती अंक दिनु हन्छ। १= त्यो सजिलोनै हुन्छ, १०= रिक्सा चलाऊनुको सबै भन्दा गार्हो पक्ष
45.How much are you concerned/ find it difficult about the distance you are pedalling for a typical trip in the scale of 1-10? तपाईंले १-१० सम्म अंक दिदा कुनै सामान्य ट्रिपमा बोक्ने भरी लाई कती अंक दिनु हन्छ।१= त्यो सजिलोनै हुन्छ, १०= रिक्सा चलाऊनुको सबै भन्दा गार्हो पक्ष

Appendix 2: Weekly data collection questions

Date:

Trip no.	Time taken for the trip	Route of the trip	Distance driven in the trip	Amount of Load	Nature of Load	Money earned from the trip	Level of tiredness after the trip in the scale of 1-10. 1= No tiredness, 10= Fully tired and cannot go for another trip	Satisfaction from the money earned	Any type of problem that aroused during the trip

1) सामान्यतया १ दिनमा कती ट्रिप /लट रिक्सा चलाऊनु हुन्छ? (How many trips did you make with this rickshaw in a typical/normal day this week?)
2) सामान्यता रिक्सा चलाऊदा कती भार बोक्नु हुन्छ? (How much load (in kg) do you carry on average/ normally in a trip this week?)
3) आज सम्म सबै भन्दा बढी कती भार बोक्नु भाको छ? (What is the maximum load (in kg) you carried on your rickshaw this week ?)
4) आज सम्म १ दिनमा सबै भन्दा बढी कती दुरी रिक्सा चलाऊनु भाको छ? (What is the maximum distance (in km) you have been able to travel with typical load?)
5) रिक्सा चलाएर सामान्य १ हप्तामा कती पैसा कमाउनु हुन्छ? How much did you earn in this week from pedalling your rickshaw?
6) कुनै सामान्य १ हप्तामा कती पैसा बचत गर्नुहुन्छ? (How much earnings were you able to save this week?)
7) कुनै सामान्य १ हप्तामा रिक्सा मर्मत सम्भार गर्दा कती खर्च लाग्छ? (What was your weekly maintenance cost for the rickshaw?)
8) What type of maintenance did you require for your rickshaw normally? कुनै सामान्य १ हप्तामा कस्तो कस्तो मर्मत गर्नु हुन्छ?
9. तपाईलाई कुनै स्वास्थ्य समस्या छ? यदी छ भने कस्तो कस्तो लक्ष्यण देखा पर्छ? Did you have any health related issues this week? If yes describe each symptom.
10. How frequently did you have these symptoms? कती कती समयमा लक्ष्यण हरु देख पर्छ?
11) तपाईले दैनिक या साप्ताहिक रुपमा कुनै औषधी लिने गर्नु भएको छ? कती कती समयमा कुन कुन औषधी लिनु हुन्छ? कृपया बिस्तारमा बताउनुहबस। (Are there any medicines you are taking on daily/weekly basis, this week? (list the medicines and the frequency in which they are taken).

12) तपाईंले साप्ताहिक रुपमा औषधीमा कती पैसा खर्च गर्नु हुन्छ? (How much did you spend every week on medicines this week?)
13) तपाईंले रिक्सा सम्बन्धी कुनै दुर्घटना देख्नु \ अनुभव गर्नु भएको छ? (Did you experience and/or witness any accidents related to driving the rickshaw this week?)
14) दुर्घटनाको कारण के थियो? What was the reason for the accident?
15) १ देखी १० सम्म को स्केलमा तपाईंले रिक्सा चलाऊदा कतिको सुरक्षित अनुभव गर्नु हुन्छ? On a scale of 1-10, how safe do you feel driving a rickshaw?
16) आफ्नो स्वास्थ्य को कारण ले तपाईंले गएको १ हप्तामा कतिपटक डाक्टरलाई भेट्न खोज्नु भएको थियो? (How many times did you feel you needed to visit a doctor due to your health condition in the past 1 week?)
17) १ देखी १० सम्म को स्केलमा तपाईं अहिले कतिको स्वस्थ अनुभव गर्नु हुन्छ? १= जतिबेला पनि थकित र बिमार, १०= अती स्वस्थ।(On a scale of 1-10, how healthy do you currently feel? 1= very tired and sick all the time, 10= excellent health)
18. तपाईंले १ दिनमा कती मदिरा सेबन गर्नु हुन्छ? (मात्रा लिटरमा) (How many alcoholic drinks do you have on a typical day? (Amount in # of drinks)
19. मदिरा सेबन मा दैनिक कती पैसा खर्च गर्नु हुन्छ? (How much do you spend in a day in drinking alcohol? (Nrs))
20. How many cigarettes do you smoke in a typical day? १ दिनमा कतिओटा चुरोट सेवन गर्नु हुन्छ?
21. How much tobacco do you consume on a typical day? १ दिनमा कती सुर्ती सेवन गर्नु हुन्छ? (मात्रा पटक)
22.On a scale of 1-10, what is your current level of stress or tension (about anything- finances, health, family, food, kids education, future, housing, etc.) 1= no stress in life, 10= very stressful every day १ देखी १० सम्म को स्केल मा तपाईंले आफ्नो तनाब र चिन्ता लाई कती नम्बर दिनुहुन्छ? तनाब जुन बिषयमा पनि- आर्थिक, स्वास्थ्य, परिवार, बच्चाको पढाई, भबिस्य, घर)
23. On a scale of 1 to 10, how physically strenuous would you rate rickshaw driving? १ देखी १० सम्म को स्केल मा तपाईंले रिक्सा चलाऊनुलाई शरीरइक तनाब को हिसाबमा कती नम्बर दिनुहुन्छ? १= एकदम आनन्द पूर्ण, १०= एकदम गाह्रो
24.How much do you rate for the difficulty of load you carry on the back on the scale of 1-10? 1= indifferent about it, 10= most difficult aspect of driving rickshaw तपाईंले १-१० सम्म अंक दिदा कुनै सामान्य ट्रिपमा बोक्ने भरी लाई कती अंक दिनु हन्छ। १= त्यो सजिलोनै हुन्छ, १०= रिक्सा चलाऊनुको सबै भन्दा गार्हो पक्ष
35. How much are you concerned/ find it difficult about the distance you are pedalling for a typical trip in the scale of 1-10? तपाईंले १-१० सम्म अंक दिदा कुनै सामान्य ट्रिपमाचलाऊने दुरीलाई कती अंक दिनु हन्छ।१= त्यो सजिलोनै हुन्छ, १०= रिक्सा चलाऊनुको सबै भन्दा गार्हो पक्ष

Appendix 3: Sample of data calculation for the case studies

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Date	Remarks	Trip #	From :	TO	Distance(Km)	Type of load	Load(Kg)	Time(min)	Income(Rs)
March 14		2	basundhara	dhapasi	3	chair	40	40	300
March 14		3	basundhara	dhapasi	4	table	40	40	300
March 14		4	basundhara	kharibot	4	iron sheet	120	20	400
March 14		5	basundhara	ranibari	5	iron angle	150	30	400
March 14		6	basundhara	chakrapath	1.5	rental items	100	20	300
March 15		1	basundhara	dhumbarahi	5	white cement	40	30	300
March 15		2	basundhara	basundhara	1	white cement	100	10	200
March 15		3	basundhara	dhapasi height	4	iron rod	130	40	300
March 15		4	basundhara	dhapasi	3	wall putty	40	30	250
March 15		5	basundhara	ganeshthan	7	cement	250	40	400
March 15		6	basundhara	baluwataar	6	pipe	40	30	300
March 16		1	basundhara	chabahil	1	commode	20	10	300
March 16		2	basundhara	lajimpaat	10	wardrobe	40	60	400
March 16		3	basundhara	dhapasi	3	iron items	150	30	400
March 16		4							
March 16		5							
March 16		6							
					Average Distance		Average Load	Average Time	Average INCOME
E					4.575		85.625	32.03125	348.4375
					Total Distance		Total Load	Total Time	Total INCOME
					146.4		2740	1025	11150

Appendix 4: Challenge log of a rickshaw driver

CHALLENGE LOG - ERICKSHAW CONVERSION FEASIBILITY STUDY (March-April 2019)

S.N.	Challenge Type	Challenge Details	Date feedbac	Planned Changes	Changes Made	Date of Change made
1	Mechanical	Not a standard size rickshaw.	Feb 20	Chasis and frame resized	The chasis was heated and forged to new dimension. New changes	
2	Behavioral	The rickshaw driver bursted in anger that he will not install the kits as it was getting delayed	Feb 22	Soothe him by assuring him to Resize the	Went to the black smith again and guided him to resize the chasis. T	
3	Mechanical	The chain of pedal system didnot matched (either too long or too short)	Feb 23	Keep the chain in sprocket by adding or r	Kept the chain tight	
4	Mechanical	Box became too large for keeping it under the flat roof.	Feb 24	Resize the box	Box size reduced and provided ventilations for the batteries.	
5	Mechanical	Batteries fell to a side breaking the wires	Feb 25	Fix the batteries.	Done by using Acc block.	
6	Mechanical	The tight chain and sprocket eroded the shaft making depression	Feb 26	Prevent the erosion	Kept some tin sheets in the bush for few days but again removed th	
7	Mechanical	The spikes that fit in the hub too small to support the load that these rickshaw drivers carry and drives through very rough road	Feb 18	Square rod welded between rim and hub	Square rod welded between rim and hub	
8	Mechanical	Welded square rod got broken	Feb 25	try new welding	whole rim changed with iron ring around the hub and rebating as the	
9	Mechanical	Tire touched the supporter(spring)	Feb 25	keep spring away from tires	drilled new holes in the wooden frame for springs	
10	Mechanical	Wire got detached from MCB during the trip	Feb 30	solve it soon	Went to the spot through bike and solved it at that spot.	
11	Behavioral	Some other rickshaw drivers pulled the wires of controller making short circuits in the system and burning a lot of wires making the controller useless	Feb 30	Visit the spot and repair	Changed the controller and kept it inside the metallic box.	
12	Mechanical	Reverse switch didnot work	Feb 30	Repair it	Reverse option removed from the rickshaws	
13	Mechanical	Horn didnot work	Mar 2	Repair it	connected the broken wire inside the headlight box by soldering	
14	Mechanical	connector between the axle and chassis got severly cracked	Mar 4	Repair it	Welded it together adding additional metal sheets making it stronger	
15	Mechanical	The bolts supporting brake got loosen, and even the brake got dismounted during the trip	Mar 4	Fix the brake	Regular inspection of the nuts and trained drivers to do by themselve	
16	Mechanical	Bearing got damaged	April 1	Change the bearing	Bearing was changed along with the new rebate	

Appendix 5: Images of the modified rickshaw and components

Image 1: Electrically assisted cargo carrying rickshaw

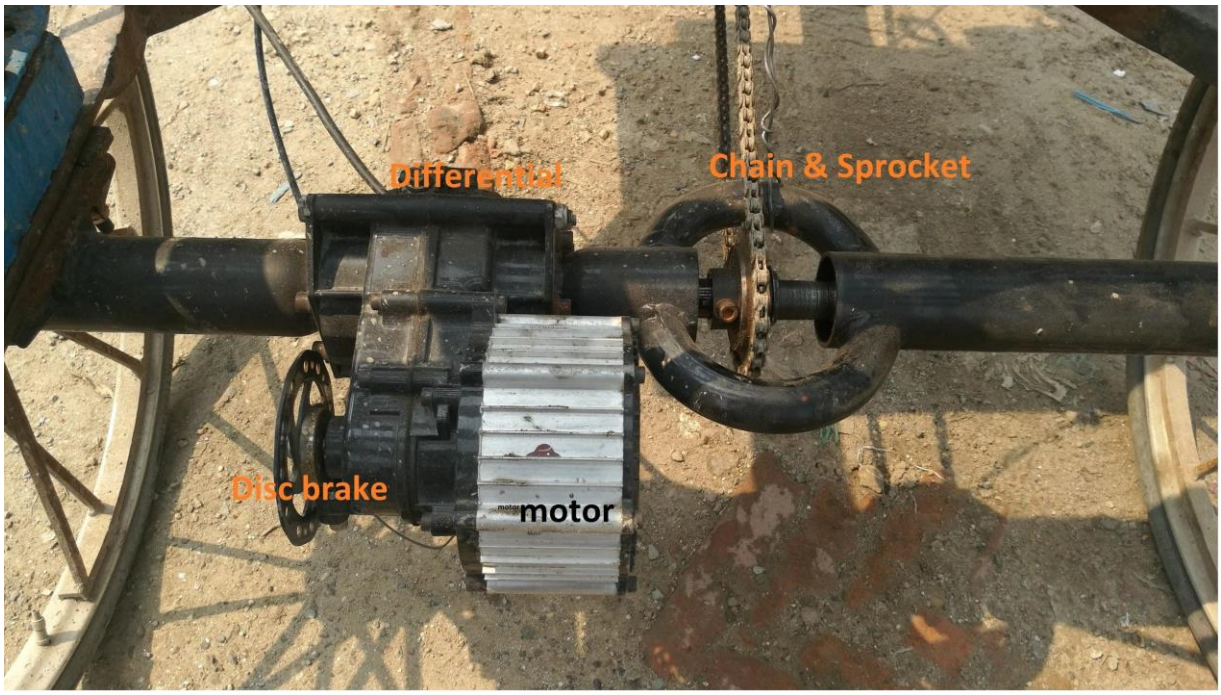

Image 2: Transmission system with differential

Image 3: Transmission system without differential

Image 4: Controller (on the left) and accelerator (on the right)