A Study on Design and Implementation of a Community Rideshare Model on Regular Mobility Needs in Emerging Countries

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A Study on Design and Implementation of a Community Rideshare Model on Regular Mobility Needs in Emerging Countries

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Abstract

A travel behavior is determined by four major factors i.e., travel safety, travel duration, cost performance, and comfort. Besides the traditional public and private transport, a semi-private mode like ride-hailing services cover individuals' demands like ride-hailing services. Ridesharing in form of car-pool, school bus, staff bus etc. has existed from the past. A new transport concept called Mobility as a Service (MaaS), mostly popular in European countries integrates several transports and offers a one-point service platform to book a tour for a group or individual for long distance travels. This research focuses on mobility within a community where the trips are regular and short distanced. Community buses exist in Japan to cover rural areas, but these are highly subsidized. An emerging country cannot afford that. A community has different types of mobility needs and requires multiple services. Private car use by individual to meet these requirements is not financially viable, nor environmentally suitable. The public or semi-public transport cannot meet the specific community mobility needs.

Some fundamental differences are observed in transportation service development process of advanced and emerging countries. Policy and infrastructure come first and then the application to make efficient use of the infrastructure in advanced countries. On the other hand, in emerging countries, the sequence is completely the opposite. Applications comes first and then it drives the infrastructure development in an organic way. In Bangladesh, rideshare applications were first installed, affordable users switched their travel options to rideshare. New demand for new vehicles, roads, and policy have been created. Road safety, congestion in urban areas, ultimate regular commuting expenses are common concerns which motivated us to design a community rideshare model to maximize community benefits. No solutions or studies on such community rideshare model has been introduced before. This research introduces a new concept of "community rideshare" and proposes a model, called SSW (Social Services on Wheels). Two communities (one urban and one rural with different demographics) in Bangladesh are studied, their travel behavior as well as the performance of SSW are presented.

First, this research carried out two separate surveys in two different communities to understand their daily mobility needs and their current travel behavior. The communities are: (1) Urban Small and Medium Enterprise (SME) (n=314) and (2) a rural community (n=83 households). Some of the

findings of the survey are previously known but the study lists the consequences and root causes which become important element for designing the proposed SSW model. The common characteristics are: (a) Short distance but long travel duration due to multiple transfers, longer route, waiting time and congestion; (b) No timetable of public transportation causes uncertainty of transport availability and failing to arrive destination on time with consequences of less productivity and bad impression; (c) Unsafe and insecure transports cause accidents, occurrence of incidents like theft, sexual harassment etc. The unsafe route and transport facilities ultimately cause problems like dropouts of high school girls in villages. Bad transport system also negatively impact SME employees work performance by causing lateness in arrival and irritating mental status.

Second, this study proposes an SSW model to meet the travel needs (guaranteed transport, on-time arrival, safe and comfortable ride, door-to-door service ensuring minimum hops and walking). The model also considers value-added services like in-vehicle office facilities including Wi-Fi and printing services. The model was configured for two studied communities to collect experiment data.

Third, two social experiments were conducted in two communities (a) SME community (2 months, 20 SMEs in one complex, two 10-seated-vans with 18 selected employees on two routes) and (b) rural community (2 months, 83 households, one 10-seated-van). Experimental data e.g., pickup time, drop off time, pick up and drop off points, vehicle movement and pause duration were collected by using our own developed software system and Google APIs. The collected data were analyzed to understand both qualitative and quantitative travel behavior e.g., increased travel safety, reduced travel duration, increased cost performance and increased comfort. As SSW offers door to door service, number of hops become zero, the waiting time in the road can ideally be saved 100%. The benefits of SSW for urban SME community are reduced number of hops and reduced waiting time, and increased safety and comfort; the cost performance was satisfactory. SSW for rural high school girls reduced walking distance almost 10 times (from 5km to 0.5km) and 70-110 minutes of walking, provided safer and comfortable travel environment, reduces risk of sexual harassment and eve-teasing during school commute. In rural areas, apart from school bus service, more services (e.g., healthcare, goods delivery, emergency car, internet service etc.) were required to designed for financial sustainability.

Future work of this research would be identifying the criteria of potential users of SSW service in different communities. An extension of SSW service for Urban family mobility is also in consideration. This model can also be applied in rural areas of developed countries where transportation system slacking due to depopulation. Studying its application in such areas would also create valuable knowledge.

Published Papers

1. Nuren Abedin, Md. Mahmudur Rahman, Muhammad Ismail Hossain, Kenji Hisazumi, and Ashir Ahmed, "Travel behavior of SME employees in their work commute in emerging cities: a case study in Dhaka City, Bangladesh", Sustainability 2020 12(24) December 2020
2. Nuren Abedin, Kenji Hisazumi, and Ashir Ahmed, "Affordable Rideshare Service for female urban corporates in developing countries: A case study in Dhaka, Bangladesh", The 21^{st} International Conference on Human-Computer Interaction (HCII-2019), Orlando FL, Springer Communication in Computers and Information, volume:1088, pp:283-289.
3. Nuren Abedin, Jecinta Kamau, Kenji Hisazumi, Akira Fukuda, and Ashir Ahmed, "Ride-share in compromised transport resources area areas of Japan: Case studies in Itoshima City, Yame City and Tango town", The 2^{nd} International Conference on Healthcare, SDGs and Social Business 2018, Fukuoka, Japan, in Proceedings of the 2^{nd} International Conference on Healthcare, SDGs and Social Business 2018, pp: 49-52.
4. Nuren Abedin, Jecinta Kamau, Muhammad Ismail Hossain, Rafiqul Islam Maruf, Akira Fukuda, and Ashir Ahmed, "A case study to design a mobility as a service model for Urban Female Corporate to Improve their work performance", IEEE Region Ten Conference (TENCON) 2017, Malaysia, in Proceedings of IEEE Regional 10 Conference (TENCON) 2017, pp: 1445-1450.
5. Nuren Abedin, Kazi Rafiqul Islam, Akira Fukuda, and Ashir Ahmed, "ICT-based family and female-friendly car-sharing for meeting families and women's mobility needs in developing countries- Is it financially suitable?", The 1^{st} International Conference on Healthcare, SDGs and Social Business 2017, Proceedings of the 1^{st} International Conference on Healthcare, SDGs and Social Business 2017, pp:9-10.
6. Nuren Abedin, Jecinta Kamau, Hironobu Kitaoka, Hiroshi Okajima, Akira Fukuda, and Ashir Ahmed, "Providing safe and affordable transportation to reduce female students dropout: a case study on college girls in rural Bangladesh", IEEE Systems, Man and Cybernetics (SMC) 2016 Budapest, SMC2016-Conference Proceedings, pp: 4130-4134.

In memory of my loving mother, my extremely supportive spouse, and loving family.

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List of Abbreviations

BUET	Bangladesh University of Engineering and Technology
C-MVP	Cluster-based Multivariate Probit
CNG	Concentrated Natural Gas
ICT	Information and Communication Technology
IT	Information Technology
MaaS	Mobility as a Service
PHC	Portable Health Clinic
RDS	Rideshare Service
RQ	Research Question
SSW	Social Services on Wheels
SME	Small and Medium Enterprise
STAR	Space-Time Activity Research

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Chapter 1

Introduction

There have been numerous works regarding travel patterns, transportation, use of ICT in travel management etc. However, one big gap in studies of travel behavior is that it does not draw a clear line between mobility of an individual and mobility of a community. Individual mobility patterns or travel behaviors are mostly reflected in the majority of travel and transport studies. Several studies exist on community mobility for children's school commute, household mobility, mobility of elderly and dependents [1] [2] [3] [4]. Car-pool for work commute in developing countries in the past [5]. Community mobility in emerging countries has long missed the attention of researchers. This research is an effort to reduce the gap in knowledge regarding community travel behavior. In this study, a community (for mobility) is defined as a group of people traveling for the same purposes (e.g., for work education, errands etc.) with similar travel attributes like source zone, destination location, travel timetable. Community travel behavior in emerging countries has been one of the least explored topics.

1.1 Digital Transformation of Mobility Management

Transport infrastructure in developed countries is designed to accommodate maximum travel needs of different communities. In advanced countries e.g. USA, Europe and Japan, big cities are well-equipped with commuter trains and public transport systems. Use of private vehicles is prominent in areas with insufficient public transport infrastructure. Most cities in Europe possess a good public transport infrastructure. Using public transport is more encouraged in those areas than driving private vehicles with a view to turning these cities carbon neutral cities. A wide-spread use of ICT based applications are developed and used to efficiently use the current resources in forms of ride-hailing services like Uber, Lyft, Didi etc [6] [7] . Ride-sharing in form of carpool, school bus, staff bus etc. has existed from the past. A new transport concept called Mobility as a Service (MaaS) integrates public and semi-public modes to offer efficient transport solution in one platform. MaaS is popular mostly in European countries [8] [9].

Cities in emerging countries still lack a proper form of public transportation system. Buses are the major form of public transports there. Due to the lower purchase ability of people, owning a car is not affordable for majority in those countries. Besides the traditional public and private transport, a semi-private mode is introduced to cover individuals' demands like ride-hailing services [10] [11]. Residents of emerging cities with a demand of safe and comfortable transport and ability to afford, are more switching towards commercial rideshare services where available. However, rural areas still suffer from lack of public and on-demand transport infrastructure [12] [13].

The MaaS service offers a single service and for individual's needs for long distance travel. Our research focuses on short distance regular transport within a community. Community buses exist in Japan to cover rural areas, but these are highly subsidized by the government[14]. An emerging country cannot afford that. A community has many types of mobility needs and requires multiple mobility services. Private cars can meet

these needs for an individual, however, none of the public or semi-public transport comes with a one-stop solution for individuals or communities.

It is observed that there are fundamental differences in transportation service development process in advanced and emerging countries. The demand for rideshare services in Bangladesh is growing exponentially [15]. Policy and infrastructure come first and then the application to make efficient use of the infrastructure in advanced countries. In emerging countries, the sequence is completely opposite. Application comes first and then it drives the infrastructure development in an organic way. In Bangladesh, rideshare applications were first installed, affordable users switched their travel options to rideshare. New demand of new vehicles, roads, and policies have been created. Rideshare services started the Bangladesh with motorbike sharing in 2015. But, a policy was developed two years later with the exponential growth in sale of motorbikes in Dhaka. However, Road safety and congestion in urban areas, ultimate regular commuting expenses are common concerns which motivated us to design a community rideshare model to maximize community benefits. No solutions or studies on the community rideshare model have been introduced before.

1.2 Status of Transportation in Emerging Countries

Dhaka, Bangladesh is a representative of an emerging city. It is the 5^{th} largest city in the world by population with 14.5 million people living in this city. There are approximately 7000 public buses, minibuses to deliver the commuting needs of the city people and this is considered as the main mode of transport in the city. There is no commuter train service available in the city yet. Public transport in Bangladesh is loosely organized and weakly regulated [16], [17] [18].

There are two categories of transports – public and private. A semi-private mode is introduced to cover individuals' demands like ride-hailing services. Figure 1.1 illustrates

the available transport modes in our study location Dhaka, Bangladesh. Bus, Train, Leguna (a type of human hauler vehicle), rickshaw (a three-wheeled vehicle that can be manual or battery powered) are some most prominent public transport of Dhaka city. These modes operate on a pre-defined route on their schedules. Private cars are owned by 2% of the population. Motorbikes and bicycles are the other two types of privately owned vehicles. Taxis are available in form of four-wheel-automobile (known as cab) or three-wheel natural gas-fueled vehicles (locally known as CNG taxis). Taxis are open to all for use on the passengers ride demand for route and schedule. Ride-sharing in form of carpool, school bus etc. has existed from the past which are closed accessed and with pre-defined.

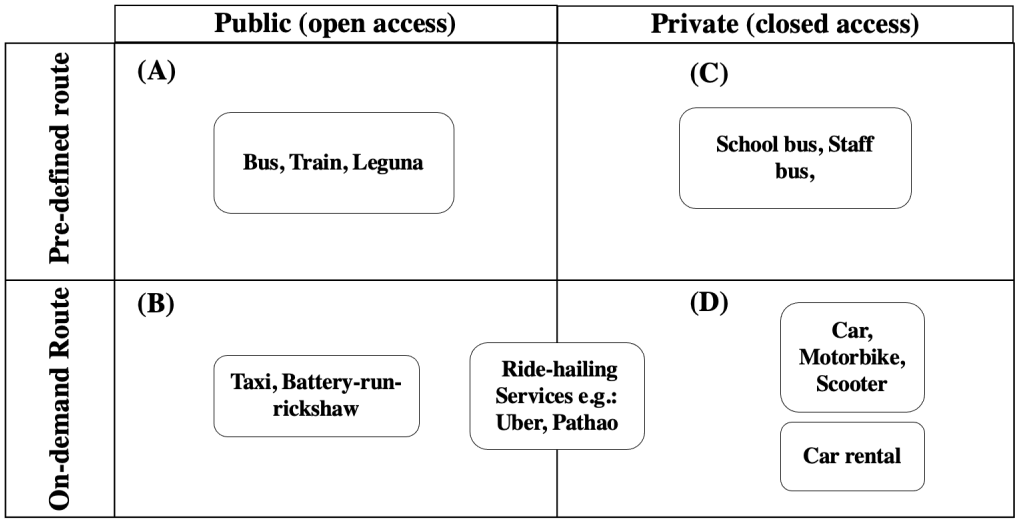


Figure 1.1: Classifying available transportation in Dhaka, Bangladesh

Commercial ride-hailing services can be classified as a semi-public on-demand transport because only registered users have access to use such services. Sakib et.al., (2019) studied the status, challenges and perspectives of rideshare services in Bangladesh [19]. He found that 77% people in urban city has experienced using rideshare services for the benefit of time-saving and comfort to be picked up at on-demand location. Drivers' professionalism was found a concerning point for the users of rideshare service. Another research found that speed, cost and convenience of rides are significant for customer satisfaction of using rideshare services [20]. However, all these types of transport solutions offer single type of service and for an individual's needs . A community has many types of mobility needs and requires multiple mobility services. Private cars can meet these needs for an individual, however, none of the public or semi-transport comes with a one-stop solution for individuals or communities. There are no existing studies that can meet multiple travel needs of a community.

1.3 Social Issues Associated with Transportation and their Characteristics

A report by World Bank in 2009 identified the major problems with public transports in Dhaka, which are: poor quality vehicles, low service standards, slacking in capacity comparing to demand, on-street competition for passengers, adherence to schedules and weak fare control [12]. As a result, passengers experience a plethora of problematic outcomes like high accident rate [21]; overcrowded vehicles; lack of comfort, safety and security [18]. Overcrowded transports inhibit women and minors to use the bus during rush hours [22]. Discomforts and harassment incidents like verbal teasing, groping, unwanted touches, sexual abuse etc. are often reported by female passengers of public transportation [23]. Both male and female have to experience a rough travel to work due to many intrinsic impacts like sub-standard and poorly maintained vehicles, noise of

vehicles, waiting time, vehicle modes, transfers, cost etc. [24].

According to a study [24] conducted in 2015 among 200 families living in Dhaka, the capital city of Bangladesh, people find public transportation unwanted and harmful to them for the reasons below:

1. It is unsafe due to untrained drivers and bus staffs, numerous accidents, harassment incidents inside vehicles, theft, robbery etc.

2. Commuting by public transport leaves the passengers exhausted and in an irritable mood when they commute using public transports and this harms their productivity at work.

3. Public transports are less cost effective as it comes with energy cost and psychological cost along with monetary cost. Commuters do not get satisfactory service in return for what they pay.

Unavailability of alternative transport mode is forcing these 2015 study respondents to use the traditional modes of transport even if those transport modes come with such shortcomings. As a result, ridesharing services is Dhaka is getting more popular. Uber, the biggest global ridesharing company, started its service in Dhaka in 2016. The huge demand for ridesharing services has influenced several similar domestic ridesharing services in Dhaka including bike share. Most of the existing ridesharing services in Dhaka use 4-seat private cars and provide pick-n-drop service for individuals or single ride at a time [25] . Thus, it gets expensive and is not an affordable choice for daily commuting to work.

Commercial ridesharing services are mainly designed for passengers from all walks of life who can afford their services. The type and nature of commuting needs of community mobility have long missed the attention. An appropriate mode of transportation to accommodate community mobility has already existed in the form of school bus, staff bus, hospital bus etc. however, digitization of such mobility services is yet to come.

1.3 Social Issues Associated with Transportation and their Characteristics

According to Bangladesh Telecommunication Regulatory Commission (2020), there are 101 million people (63% of the population) using internet in Bangladesh [26]. As an alternative solution to unreliable public transport, people of Dhaka city are more shifting towards using transport services that are accessible through the use of internet. Thus, ride-hailing services are also getting popular in Bangladesh. However, these commercial rideshare services are designed for all types of users and purposes. None of these rideshare services are specifically designed for SME employees for work travel purpose. However, with the growing trend of economic activities, more men and women are traveling for work on a regular basis, conveys dissatisfaction with the existing transport system of Dhaka City.

The common characteristics are:

- Short distance but long travel duration due to multiple transfers, longer route, waiting time and congestion
- Irregularity of transport causes uncertainty of transport availability and failing to arrive destination on time with consequences of less productivity and bad impression
- Unsafe and insecure transports cause accidents, occurrence of incidents like theft, sexual harassment etc.

The unsafe route and transport facilities ultimately cause problems like dropouts of high school girls in villages [27] . Urban parents make compromises to their work to chauffeur their children. Bad transport system also negatively impact SME employees' work performance by causing lateness in arrival and irritating mental status.

1.4 Research Motivations, Objectives and Position of our Research

As stated above, there have been numerous works regarding travel patterns, transportation, use of ICT in travel management etc. However, one big gap in studies of travel behavior is that it does not draw a clear line between mobility of an individual and mobility of a community. An Individual mobility pattern or travel behaviors are mostly reflected in majority of travel and transport studies. There are several studies of community mobility for children's school commute, household mobility, mobility of elderly and dependents. Car-pool for work commute in developing countries in the past. Community mobility in emerging countries has long missed the attention of researchers. This research is an effort to reduce the gap in knowledge regarding community travel behavior. In this study, a community (for mobility) is defined as a group of people traveling for the same purposes (e.g., for work education, errands etc.) with similar travel attributes like source zone, destination location, travel timetable. Community travel behavior in emerging countries has been one of the least explored topics.

The research has the following major objectives:

1. To understand the travel behavior of communities in emerging countries for regular and short distanced travel

2. Design and implement a community rideshare model that meet the community travel needs

3. Conduct social experiment of the proposed model and evaluate the performance

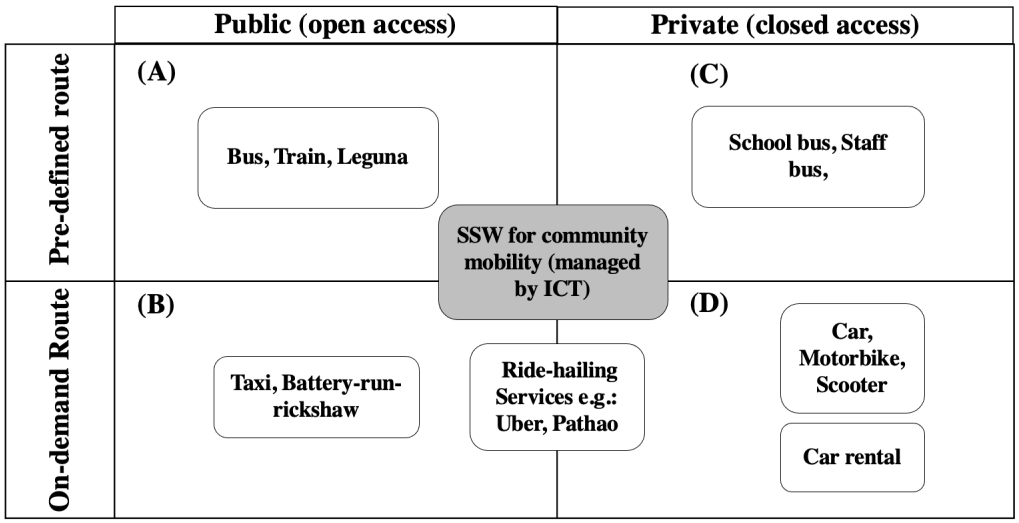


Figure 1.2: Position of our research

Fig1.2 illustrates the position of our research. The proposed model for addressing the need of community shares attributes from the four classifications of transport modes in emerging countries. The proposed model would operate on pre-defined and on-demand routes, will be open to only registered users of a certain community, but any rider from that community can register for using this service.

1.5 Thesis Outline

The rest of the paper is organized as follows: **Chapter 2** describes the recent travel behavior and mobility needs for Urban SME community. Thanks to the recent ICT based transportation management system, travel behavior has been changed in urban areas. This chapter reports the new problem associated with the changes. Travel behavior is defined by four major components- travel safety, travel duration, cost performance and comfort. Travel behavior related information was collected from both literature and

questionnaire based survey. Travel needs for this community were extracted from the questionnaire survey and the findings are illustrated in this chapter. However, ICT based transportation management system or rideshare services are not available in rural areas. Therefore, travel behavior and the needs are different from urban community. **Chapter 3** focuses on a rural school girl community. The travel pattern, issues and needs are described. Based on the needs of both communities, we designed a new rideshare model, we call it SSW. The system architecture, the components of SSW, the services provided by SSW are described in **Chapter 4**. Social experiments by using our SSW model have been conducted in two pilot areas. The experiment environment, the findings and social impacts are explained in **Chapter 5**. Finally, **Chapter 6** concludes the study with its major contributions, implications of research, limitations and future works.

1.6 Publication

1. Nuren Abedin, Jecinta Kamau, Kenji Hisazumi, Akira Fukuda, and Ashir Ahmed, "Ride-share in compromised transport resources area areas of Japan: Case studies in Itoshima City, Yame City and Tango town", The 2^{nd} International Conference on Healthcare, SDGs and Social Business 2018, Fukuoka, Japan, in Proceedings of the 2^{nd} International Conference on Healthcare, SDGs and Social Business 2018, pp: 49-52.

Chapter 2

Travel Behavior and Mobility Needs of Urban SMEs Community

This chapter describes the travel behavior in terms of travel safety, travel duration, cost performance and comfort. Travel behavior of an individual differ from the behavior of a community.

2.1 SME Community Travel Behavior

The fundamental characteristics of SME employees commuting are that (a) the employees live in different parts of a city (b) they have to arrive at offices by a prefixed schedule and leave the office on a prefixed schedule as well. It is possible to provide a ride service for a number of employees with the same route and schedule for their work commute in the morning and evening. Similarly, commuting for executing company errands as a pattern. company errands like going to banks, post office, procurement, government officers, procure supplies, delivering goods etc. has common destination and

route for companies located in the same location. It is possible to provide scheduled shuttle bus service for executing this company errands within a period of time. Some other mobility needs of SME companies would be going to irregular locations for meetings and visits. An SSW model is proposed that provides pre-scheduled and on-demand services for these commuting needs of SME community. Three major services are selected for the proposed SSW.

- Staff bus for employees in the morning and evening
- Corporate errand shuttle bus during noon and afternoon time, and
- On-demand ride during idle time and weekends.

To design and investigate the suitability and performance of this model, a survey was conducted regarding travel behavior pattern of this community and administered a pilot experiment in the study location.

Understanding the travel pattern of commuters is quite straight forward. The work time of almost all the employees is similar. The offices in Dhaka city start at 10:00 and end at 18:00. However, there are exceptions. People travel from different part of the city. Employees use different modes of transports depending on the availability, comfort and affordability. Fig 2.1 illustrates Location of employee residences around the workplace location and their commute pattern.

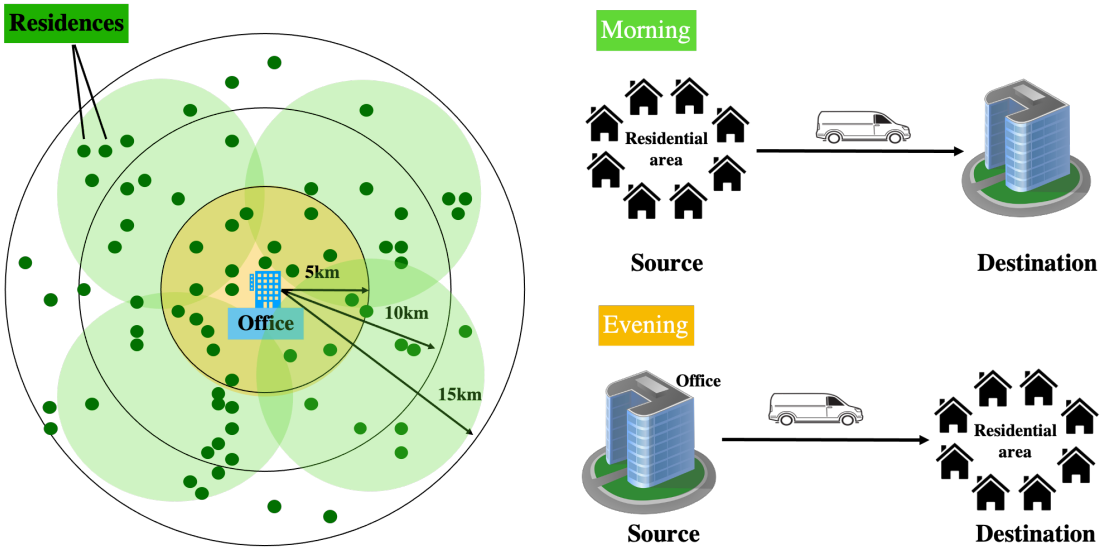


Figure 2.1: Location of employee residences around the workplace location and their commute pattern

2.2 Survey on SME Community Travel Behavior

Based on the studies mentioned above, the following research questions (RQs) are adapted to understand travel behavior of the target community:

RQ1. What are the employees' commuting distances for work?

RQ2. What primary modes of transport do they use to commute to work?

RQ3. How much time do they use for work commute?

RQ4. What is the travel expenditure pattern?

RQ5. What the consideration points for choosing a mode of transport?

RQ6. What is their attitude towards using rideshare services?

Information regarding the above questions were collected by conducting a survey among SME employees who commute to work regularly to a common location or vicinity.

2.2.1 Study Profile

In order to understand the travel pattern of SME, a survey was carried out in Dhaka city, Bangladesh. The target population for survey is the working community who commutes to office daily for work. Grameen Bank Complex located in Mirpur Sector-2; west part of Dhaka city was selected as study area Fig. 2.2. This building complex houses 54 SME corporate offices where approximately 560 people commute daily for work, who travel from different parts of Dhaka city. The average employee size of them is approximately 10 people. All the SME were invited to participate in the survey. Out of 54 SME, 20 of them agreed to participate. Total number of participants is 314. Out of them, 60 were female and 254 were male. The participants belonged to different affiliations and income brackets. The study was conducted in September 2018. Fig. 2.2 shows the building of Grameen Bank Complex (picture on the left) and the location of Grameen Bank Complex in Mirpur, Dhaka City (map on the right).

(a) Grameen Bank Complex (b) Map of Dhaka City

Figure 2.2: Survey Location and map- (a) Grameen Bank Complex, (b) Location of Grameen Bank Complex in map of Dhaka city

We conducted the survey by using a questionnaire consisting of 37 questions. The questions are classified in the following 4 categories (Table. 2.1)

Table 2.1: Categories of survey questionnaire and description of questions

Category	Description of questions
Category 1: Work commute	8 questions about commuting schedule, distance, duration, route, zone, expenditure
Category 2: Personal errand commute	10 questions about types of errands, frequency, vehicles used, pattern of travel, expenditure
Category 3: Employees attitude on using rideshare services	10 questions about their knowledge about rideshare services, willingness to use, reasons for choosing or not choosing rideshare services
Category 4: Participants demographic information	8 questions about their age, gender, residential zones, boarding points, occupation, affiliations

2.2.2 Data Collection Issue: Pre-processing of Collected Data

While testing the reliability of the survey data we found some inconsistencies in the distance and commuting expense data provided by the respondents (i.e., employees of the SME). Pre-processing of commuting distance and expense data is presented below:

Pre-processing of commuting distance data: Respondents do not have exact measurements about the distance they travel from home to office. We found inconsistencies in their responses. Fortunately, the survey data contained the address of the nearest boarding points from where they start their journey from home to office. We derived the accurate distance data using Google Map for all the 314 employees and used the accurate data for our analysis.

Pre-processing of the monthly commuting expense data: Some major inconsistencies were seen in the nature of the monthly commuting expense data given by the surveyed employees (Fig. 2.3). For examples:

- Some of the employees use their own car and motorbikes for work commute. They mentioned their monthly commuting cost as 0 BDT, which is doubtful as every privately-owned vehicle incur maintenance, fuel, tax and parking cost. As they do not have to pay fare, they misunderstood the concept "cost".

- Some employees are provided office cars for their commute to work. They also

mentioned "zero" for their transportation cost. Some of them estimated their monthly cost to own and maintain a car. Therefore, we found two polarized values even for the same travel distance.

- Similar inconsistency was seen in data for traveling by bicycle. Some people mentioned "zero" and the rest mentioned the maintenance cost of the bicycle.

- A significant portion of the employees commute to work by walking. For many of them walking is the primary and only mode of transport. However, some employees who commute by walking as the primary mode of transport, use rickshaw (a three-wheeled manually driven or battery driven tricycle that can accommodate one driver and two passengers) , CNG taxis (a three-wheeler-automobile that uses Compresses Natural Gas as fuel and is used for providing taxi services, which is locally called CNG), bus etc. occasionally as well. As a result, there is incurrence of expense for commuting while walking only is not expected to incur any cost. Hence, the data of these employees were also inconsistent.

Due to the inconsistencies in the monthly expense data, we derived the data through the following four steps-

- derived the cost of using Uber rideshare service for the source and destination points for each employee's two-way and calculated the monthly costs of using Uber service for work commute for each employee.

- derived ratio of each employee's monthly cost and monthly Uber cost.

- generated the median of the ratio for each mode of primary transport.

- Each Uber cost of the surveyed employees was divided by the designated median generated for each mode of transports, and thus derived the monthly commuting costs for work commute.

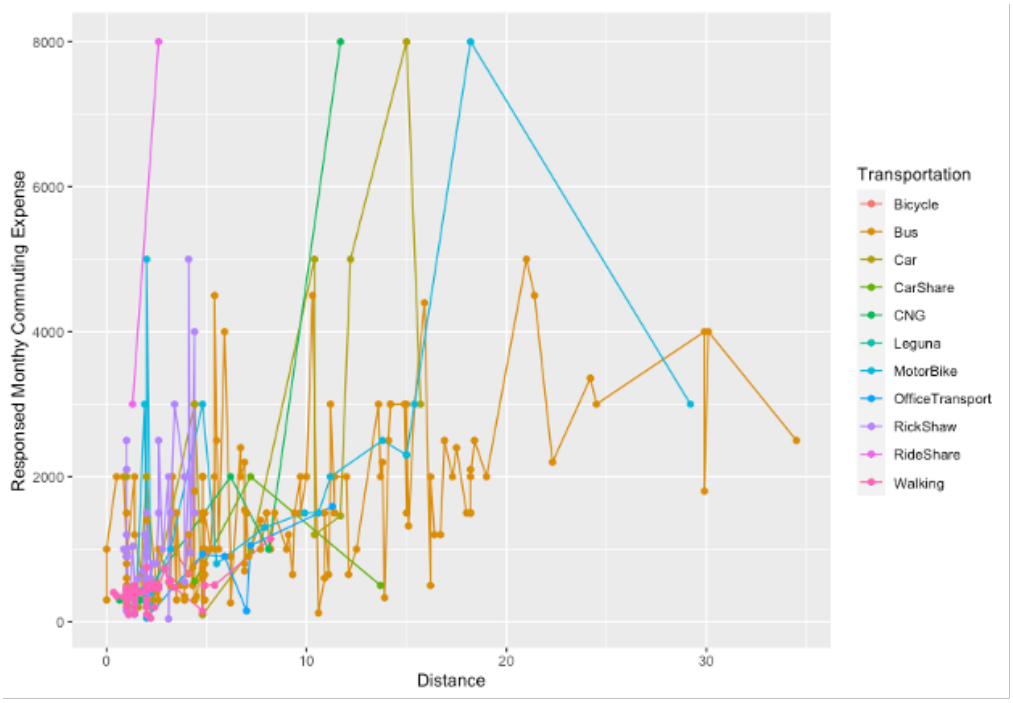


Figure 2.3: Inconsistency in response data

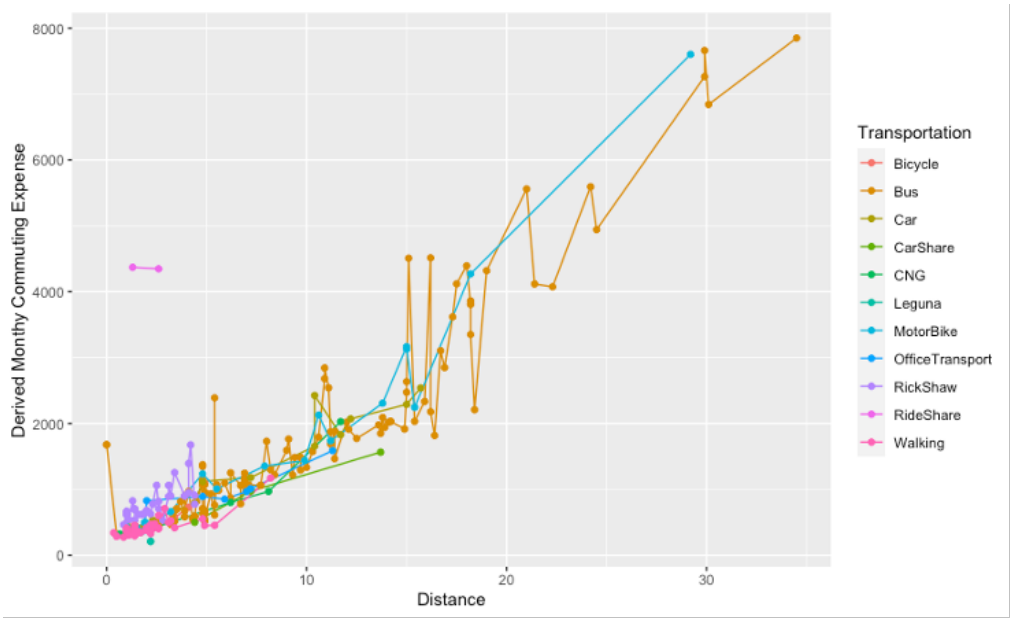


Figure 2.4: Response data after pre-processing

This way, the inconsistencies of the data are minimized and consequently increases the accuracy of the processed data (Fig. 2.4). Based on the locations of all the participants, the accuracy of all the data was manually verified.

2.2.3 Findings

The collected data was analyzed and the key observations are described as follows:

Observation-1: *The shortest distance commuted is 0.2km and the longest 35km. Approximately 40% employees commute less than 2.5km, 24.84% commute 2.6∼5.0km, 13% commute 5.1∼10.0km and 10% commute 10.1∼15.0km. (RQ1)*

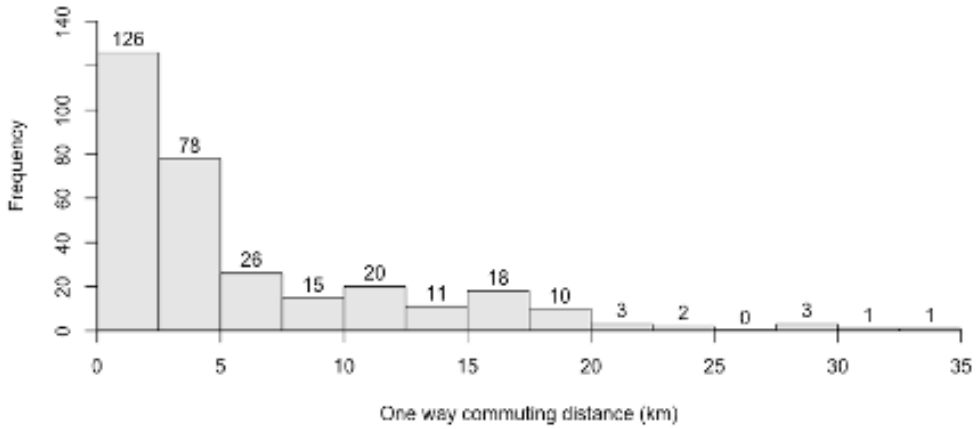


Figure 2.5: Commuting distance for SME employees to work

Fig. 2.5 shows the distance from the office to each employee's pickup points near their residence. As Dhaka is very congested during the rush hours, employees tend to find their residence near their work place. Therefore, it is observed that all the employees live within 0.2 km to 35 km. More than 40% commute from 2.5 km distance, 24.84% travels within 2.6∼5.0 km distance. Considering the culture of Bangladeshi families, children's schools, women's workplaces are given priority to select a living place. In this figure, we can observe that all the female participants are living within 20km distance, 70% of them live within 5km distance. Considering both the genders, 13% travel within 5.1∼10.0 km,

10% within 10.1∼15.0 km, 8.9% within 15.1∼20.0 km. In conclusion 47.84% participants live within 2.6∼15.0 km distance. This population is mostly using motorized vehicle e.g. motorbike, bus, CNG taxi, car etc. This finding provides an answer to RQ1.

Observation-2: *Bus, Walking and Rickshaw are the top three modes of primary transportation. (RQ2)*

The participants were asked to select the most used primary transportation mode for commuting to their office. As shown in Fig. 2.6, three most used modes of transports are bus (43.95%), walking (21.34%) and rickshaw (15.29%). Four percent (4%) of them commute using their own car and another 4% using own motorbike. The other vehicles used for commuting to work are bicycles, CNG-run taxis, car-share, Leguna (a three-wheeled light motor vehicle) and rideshare services. There is a bus stop nearby the office. There is no train service inside Dhaka city. Usage of bicycles to commute to office is not common as there is no separate bicycle lane and also there is no bicycle parking in the Grameen complex. A group of participants use multiple vehicles to come to office. During rainy seasons, people use rickshaws instead of walking. It is also observed that 50% (31 out of 60) female corporate employees use buses as their primary transportation to office.

While Fig. 2.7 explained the mode of primary transports used by the employees, Fig. 2.6 considers their distance. Employees use single or multiple numbers of transports to commute to office. Each colored bar represents inter-quartile range (25th percentile to 75th percentile) of distances traveled using each mode of transportation and the bold line insides the inter-quartile range indicates the median. The red dots represent the outliers.

Employees living within a short distance prefer to walk or use a non-motorized vehicle e.g. rickshaw, bicycle etc. It is overserved that 88.54% of the employees live within 15km distance and among them, 65.61% use non-motorized vehicles who live within 5km distance. The rest (88.54-65.61= 22.93%) of the employees use public transport (where they are victims of sexual harassment and environmental pollution) and private cars or

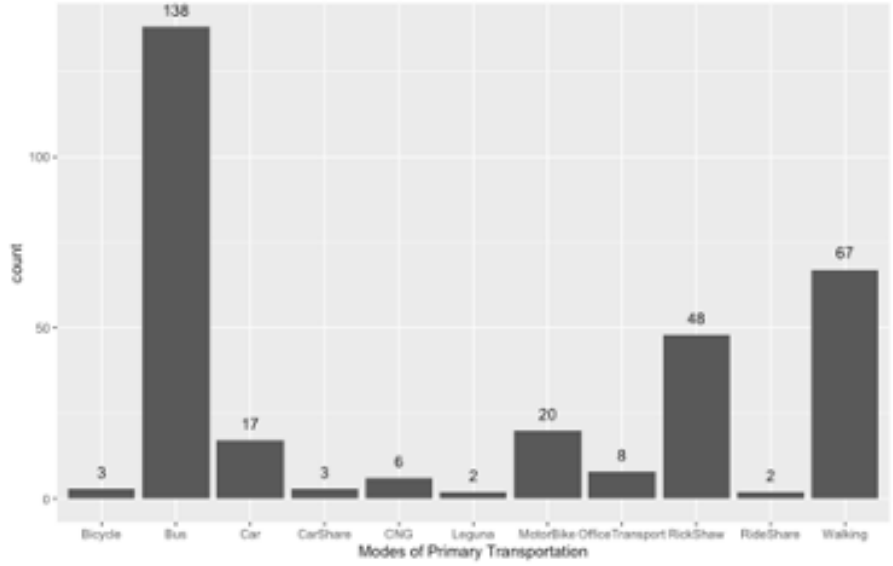


Figure 2.6: Modes used by SME employees for work commute

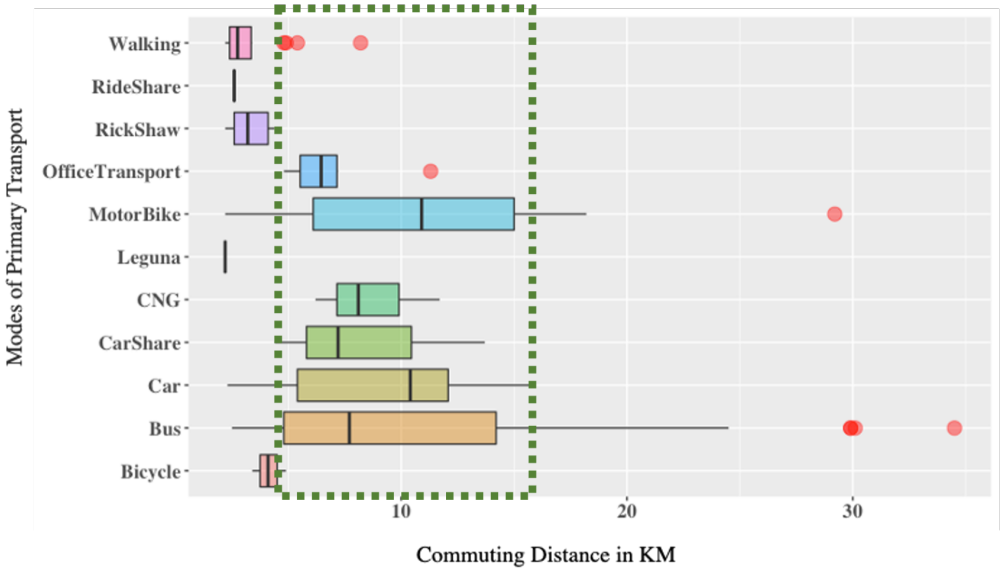


Figure 2.7: Commuting distance pattern by different modes of transport

bikes. These employees could be potential users for rideshare services to save time and increase comfort. These findings provide answers to RQ2.

Observation-3: *Travel duration for 94% people is within 60 minutes. (RQ3)*

The duration of one-way travel to work for majority of the employees (295 people,

94%) out of 314 people is within 60 minutes. Employees who reach workplace within 20 minutes are 16.56% (52 people). These are the group of people who mostly walk or take rickshaw to work. The 2^{nd} largest group is people who travels for 30 minutes to work (55 people, 17.52%). One fifth of the population travels for 30∼60 minutes to work (62 people, 19.68%). Participants who travels more than 60 minutes are approximately 5% of the participant population. Fig. 2.8 shows the frequencies for different commuting duration. It is observed that 50% (30 out of 60) female participants travel for 30 minutes. Observation 3 provides answer to RQ3.

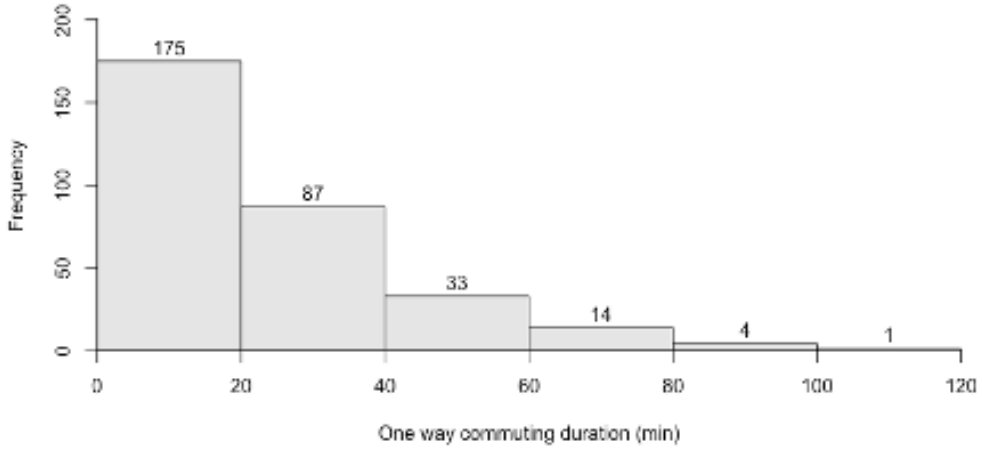


Figure 2.8: One way commuting duration and their frequencies (n=314)

Observation-4: *62.7% employees spend up to 1000 BDT, 21.02% spends 1001∼2000 BDT and 7.64% spends 2001∼3000 BDT per month for work commute. (RQ4)*

Fig. 2.9 illustrates these findings. The employees were asked about monthly expenditure of work travel. The largest group (32.8%, 103 people) spends less than 500 BDT which is equivalent to $6.25. The second largest group (29.94%, 94 people) spends withing 501∼1000 BDT ($6.25∼12.5). These two groups represent more than half of the employees (32.8+29.9=62.7%) among the total number of participants. The next largest group consists of 43 people (13.69%) who spend within 1001∼1500 BDT ($12.5∼18.75). 23 employees (7.32%) spend 1501 2000 BDT ($18.75∼25). 24 employees (7.64%) spend

2001 3000 BDT ($25∼37.5). 9 employees (2.87%) spend 3001∼4000 BDT ($37.5∼50), 11 employees (3.5%) spend 4001∼5000 (equivalent to $50∼62.5), and rest 7 employees (2.22%) spend more than 5000 BDT ($62.5) to 8000 BDT ($100).

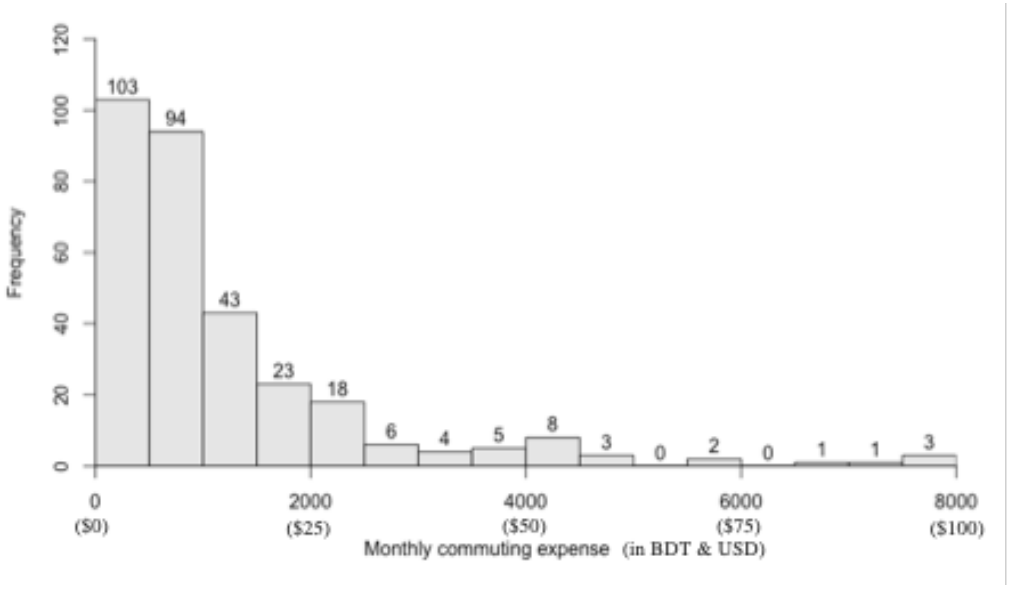


Figure 2.9: SME employees' pattern of monthly work commute expenditure

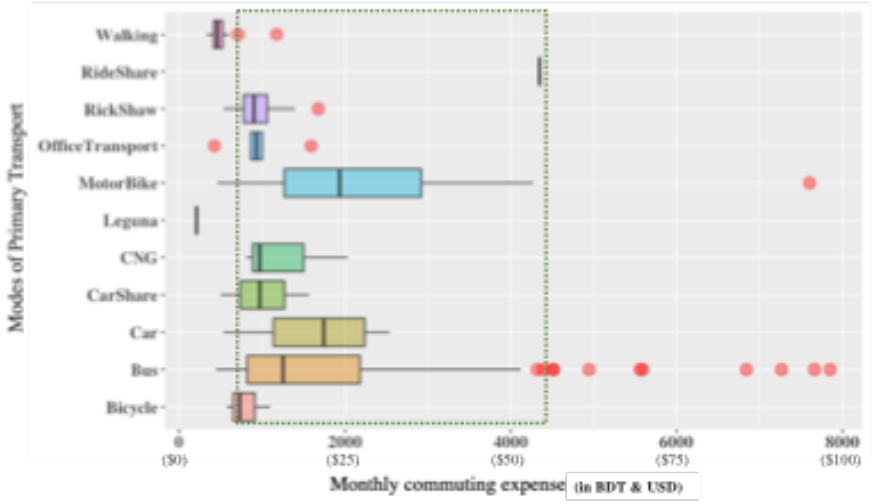


Figure 2.10: The ranges of monthly travel expense for each mode of transport used by the participants

Fig. 2.10 shows the range of spending for each mode of primary transport used by the employees in box plots. Each colored bar represents inter-quartile range (25^{th} percentile to 75^{th} percentile) of monthly commuting expenses for each mode of transportation and the bold line insides the inter-quartile range indicates the median. The red dots represent the outliers. The green dotted box inside Figure 2.10 indicates the common range of expenses (500∼4200 BDT, equivalent to \$6.25∼52.5) made by employees for using motorized mode of transportation. However, Fig. 2.10 shows Leguna and rideshare services are outside of that range. Motorbike, bus and car have the widest range of commuting expense. Public bus fare is cheap, but private AC buses are expensive. Observation4 answers RQ4.

Observation-5: *Travel time, safety and expense are considered most while choosing a mode of transport. (RQ5)*

The participants were asked to rank the factors they take into consideration when choosing a mode of transport to commute to workplace. The topmost factor for choosing a mode of transport is travel time followed by travel safety and cost. They also give importance to travel convenience and effect on health while choosing a mode of transport. Fig. 2.11shows this finding. Observation5 provides answers for RQ5.

Observation-6: *One third of the participants would like to use a rideshare service for work commute. (RQ6)*

Participants were asked if they would use a rideshare service for work. Approximately one third of the participants (102 people, 32.38%) responded positively (Fig. 2.12) . Approximately 56% of these participants use bus, 7% car and 4% motorbike. Approximately one fourth of the participants who responded positively belong to the non-motorized vehicle user group and travel less than 3km to work.

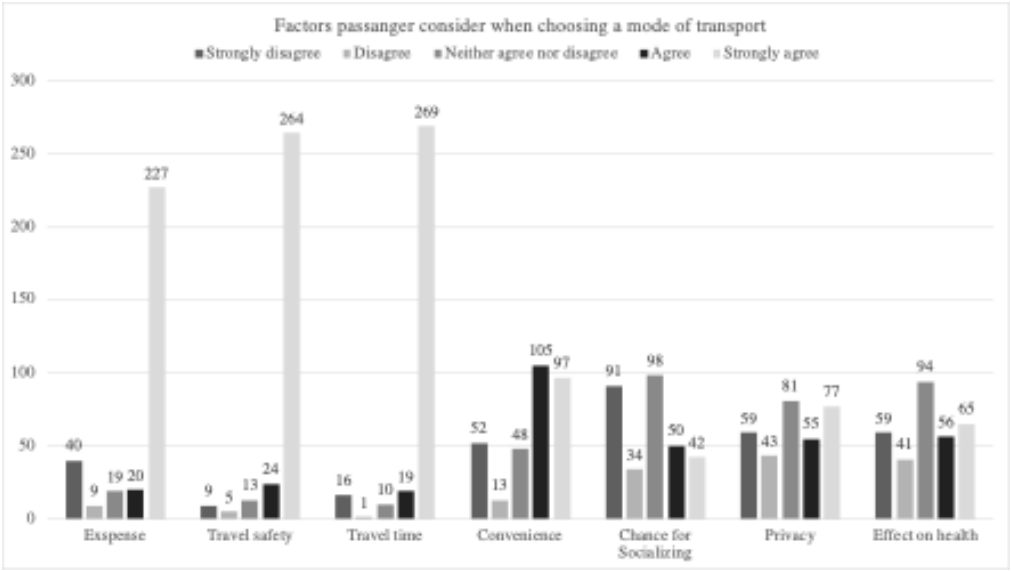


Figure 2.11: Factors considered on importance scale when choosing a mode of transport by SME employees

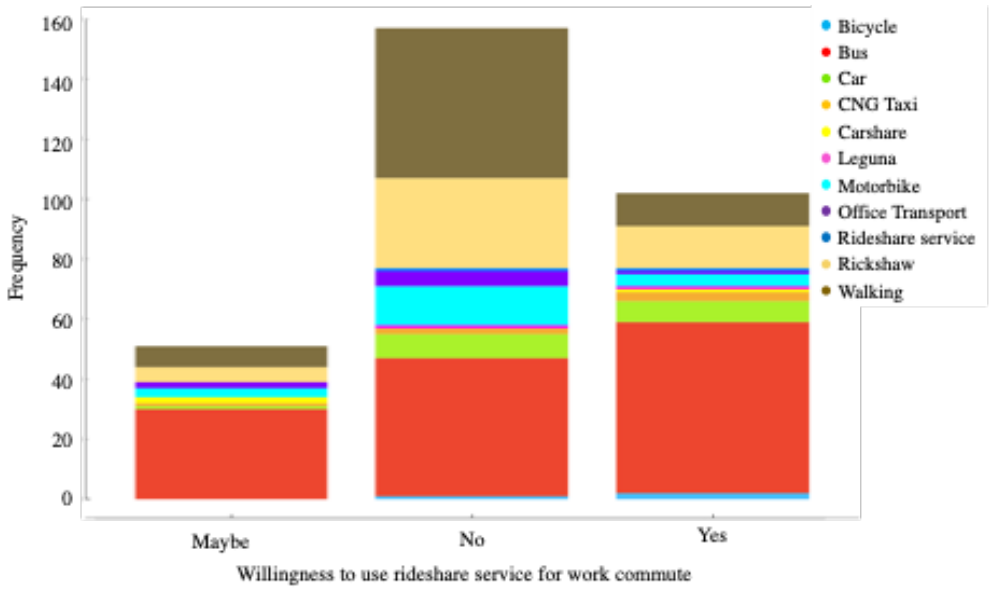


Figure 2.12: SME employees' willingness to use a rideshare to work and modes of transportation used by them in each response segment

2.2.4 Summary of the Findings

In this study, travel patterns of 314 employees working in the same office building have been observed. Survey finding on distance showed that 66% of the employees lived within a distance range of 5km from work. and 23% of them lived within the distance of 5∼15km distance range. The usual serving distance range for rideshare services like Uber, Patho etc is the middle distance that ranges withing 5∼15km [25]. This infers that 66% population of SME employees live outside the serving distance range of rideshare services. Among the employees, only 23% of the employees fall within the service distance range of these services.

It was also observed that bus (43%), walking (22%) and rickshaw (16%) are the three major transportation modes. Approximately 40% percent employees live within 2.5 km distance, the shortest commuting distance is 0.2 km and the longest commuting distance is 35 km. Employees reaching their workplace within 60 minutes travel duration is 94% and approximately 62% of the employees spend up to $12.5D for their work commute in a month.

Depending on the type of vehicle (motorized or not), the participants can be classified into two groups- (1) Non-motorized vehicle users (using walking, rickshaw, bicycle); (2) Motorized vehicle users (using bus, car, CNG-run taxi, carshare, Leguna, motorbike, office transport, rideshare). The characteristics of these two groups have similarities as well as differences which are presented in Table 2.2

Table 2.2: Characteristics of motorized and non-motorized vehicle users

Category	**Non-motorized vehicle users**	**Motorized vehicle users**
Distance	Usually travels within 0.1∼2.5km (except for bicycles commuting 3∼5 km)	Usually travels more than 2.5 km (except for some bus users commuting less than 2.5 km)
Travel Duration	Mostly within 20 minutes	Miscellaneous, within a range of 20-100 minutes
Commuting expense	Ranges from $0∼12.5	Ranges from $10∼100

RQ6 of this study seeks to find who could be the potential user of a group rideshare commute to work. From the findings, it is observed that 32% of the employees surveyed responded positively towards using a rideshare service for work, and another 18% said they might use such a service. However, half of them said they are not willing to use a rideshare service for work commute. The potentiality of an employee as a rideshare user can also be indicated by their pattern of work commute. Like employees who live within a short distance or use their own cars, or have a direct bus connection, are less potential to become a user of this type of service. Table 2.3 discusses the criteria of non-potential users of a rideshare service for work commute.

Table 2.3: Non-potential users of a ride-share service for their work commute

Category	**Non-potential rideshare user**	**Reason**
Transport Mode	Employees who come to office on foot (22%)	Motorized vehicle is not a requirement for their work commute
Travel Duration	People who arrive at the office within 10 minutes	Service would be designed to accommodate optimum passengers from an optimum furthest distance
Commuting Expense	Employees who spend no money or less than $32 a month for their work commute.	The operating cost required for providing this service would require more than $40 a month per passenger [7]
Commuting Distance	Passengers living within 2.5 km distance from the office	Optimum efficiency of service would require optimum passengers from the optimum farthest distance

On the contrary, 28% of the bus users live within 3.1∼5km, 20% 5.1∼10km, 13% 10.1∼15km and 12% 15.1∼20km distance. These groups represent 33% of the total surveyed population. Another 2.54% participants (8 people) travel by car and 3.8% participants by motorbikes for a distance of 3.1∼20 km. among the other modes used for traveling more than 3km are CNG-run taxis, car-share services and office transport. These groups could be potential users for ride-share services to work. Table 2.4 presents the potentials users of ride share services to work along with the reasoning of these users to use such services.

Table 2.4: Potential users of a ride-share service for work commute

Category	**Potential rideshare user**	**Reason**
Transport Mode	Employees who commute more than 2.5 km	Motorized vehicle is a requirement for their work commute
Travel Duration	People who can save time and who are flexible to compromise time-window	Service would be designed to accommodate optimum passengers from an optimum furthest distance
Commuting Expense	Employees who can spend more than $32 a month on their work commute.	The operating cost incurring for providing this service would require more than $32D a month per passenger [7]
Commuting Distance	Passengers living within a 2.5∼15 km distance from office	Optimum participants living below 2.5 km mostly use non-motorized mode of transport to for work commute. Optimum efficiency of service would require the optimum passenger from the optimum farthest distance

Only two out of participants among 314 meet both the affordability and distance criteria of being a potential user of rideshare service to work. However, it is difficult to understand from this study if they would be open or flexible for a time-compromise window. Also, it is difficult to understand from the findings if such rideshare would bring them time benefit.

There are 29 participants who responded "Maybe" and meet the distance criteria. But their current average travel expense is 1.5 times cheaper than the required expenses of becoming a potential user. If participants take only the financial aspect into consideration, their possibility to use a rideshare service seems to be negative.

The top three important factors SME employees take into consideration for choosing a mode of transport for work commute are travel time, travel safety and travel expense. More employees might be interested in using a rideshare service for work commute if they find more time benefit and safety benefit using such service. Hence, evidence showing time benefit and travel safety benefits for users are needed to predict the possibility of

how many participants might actually be using the rideshare service for commuting to work if offered.

It is assumed that corporate ride share services will be safer for the corporate, especially for female corporate employees. Rideshare services will be provided only to the registered members. Therefore, it would be easily tracked for any harassment. Other safety issues like theft, robbery inside the fleet are very unusual to happen. Rideshare car driver is a proper licensed person, provided corporate guidelines on driving safety and expected to occur fewer accidents than public transports.

2.3 Mobility Needs of Urban SME Employees Community

Table2.5 summarizes the problems faced by SME employees while commuting by existing transport and their mobility needs for work commute.

Table 2.5: Problems with existing transport for SME employees and their mobility needs

Problems	Needs
Reduced productivity: Difficult to predict arrival time to office as public transport does not have a timetable. Delayed arrival causes bad impression at work.	On-time arrival.
Long waiting time on road: No door to door service. Multiple hops per trip.	Less number of hops. Preferably door to door service.
Less cost effective: monetary cost, energy cost (physical strain), psychological cost (irritating mood).	Cost vs. Values. Less physical and mental strain. Reserved seats, comfortable in-vehicle environment.
Unsafe: Unwanted incidents like sexual harassment, theft, robbery.	Safe. Monitored and maintained. Reliable co-riders.

Employees need a guaranteed, regular, safe, comfortable and cost-effective transport mode that would enable them arriving at work on-time with least number of hops and least stress and strain on physical and mental condition.

2.4 Publications

1. Nuren Abedin, Jecinta Kamau, Muhammad Ismail Hossain, Rafiqul Islam Maruf, Akira Fukuda, and Ashir Ahmed, "A case study to design a mobility as a service model for Urban Female Corporate to Improve their work performance", IEEE Region Ten Conference (TENCON) 2017, Malaysia, in Proceedings of IEEE Regional 10 Conference (TENCON), pp: 1445-1450.

2. Nuren Abedin, Md. Mahmudur Rahman, Muhammad Ismail Hossain, Kenji Hisazumi, and Ashir Ahmed, "Travel behavior of SME employees in their work commute in emerging cities: a case study in Dhaka City, Bangladesh", Sustainability 2020 12(24) December 2020

Chapter 3

Travel Behavior and Mobility Needs for Rural College Girl Community

Rural areas of emerging countries barely come with a public transport infrastructure that significantly affects task performance of villagers and the quality of life in those areas. This chapter studies the transport environment of a village in a rural area, types of and travel behavior of Rural High School Girls community in an emerging country. The study location was two rural areas named Matlab in the district of Chandpur and Bedarganj in the district of Shariatpur, Bangladesh.

The study found that the only transport available in rural areas for commuting are rickshaw and human haulers (e.g.: Leguna, Easy bikes). Rural high school girls travel for 180-230 minutes regularly for 5-11km (one way) for education. They walk in average 5km one way for reaching the nearest transport hubs for Leguna and Rickshaw.

Long walking requirements to reach transport hubs, lack of an operation timetable, crowded and bad quality vehicles were found as the problems associated with the rural

transport system. Rural high school girls have dangers of experiencing eve-teasing, sexual harassment and sex crimes against them during the long walk from home to transport hubs. This is one major cause of drop-out and early marriage. Uncertain and crowded vehicles were also found a cause of absenteeism. Rural high school girls need a guaranteed, on-time, safe and comfortable transport mode that would pick up and drop-off to nearby locations to their boarding point and destinations.

3.1 Rural Community Travel Behavior

Sustainable Development Goals (SDGs), particularly Goal-4 aims to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all [28]. One of the targets to achieve this goal is to eliminate gender disparities in education and ensure equal access to all levels of education. Goal-5 of SDGs aims to achieve gender equality and empower all women and girls and targets to eliminate all forms of violence against all women and girls in the public and private spheres [29] . In this work, we investigate the status of the adolescent female students' education in rural areas of developing countries and the challenges to access to education facilities.

Ethiopian boys have more access to education than Ethiopian girls. The number of female drop-outs is high in the country, especially in the transition from primary to secondary education. In 2009, only 41% of girls survived to the last grade of primary education and there were only 30% enrolled in secondary education. Over 1.8 Million adolescent girls were out of school in 2009 [29]. Poverty has been considered to be the biggest challenge for access to education. Niringiye Aggrey et, al [30] studied the academic performance of female students inside Dar es Salam University but did not mention any correlation between the performance and the transportation facilities. Sixty drop-out girls in the upper west region of Ghana were investigated to know the reason for drop-out and twenty-seven of them indicated financial problems [31]. However, twenty-

two of them were not engaged with any jobs after their drop out. Fata No et.al added several important predictors, such as distance to school, security risks, late school entry and early marriage [32]. Yet there are many other challenges associated with education and "Safe Access to Education" is one of those. Lack of safe access stops especially for children and girls in rural areas of developing countries. Female adolescent students are one of the most vulnerable groups in this scenario. For village girls, access to education comes with a big opportunity cost. The cost lies in the existing transportation system that cost them a significant proportion of time, money, and hard physical labor and tolerate many kinds of discomfort and harassment while commuting to the school. A female friendly transportation system is yet to offer in the rural mainstream transport infrastructure for adolescent female students, causing many crimes against women and discouraging women's participation in education and economic activities.

In our earlier work, we investigated the scenario in a rural area in Bangladesh. Public transportation is almost absent [27]. Some small-scale private entrepreneurs provide ad hoc transportation services. These private transports acts as a mode of access to education and other social welfare services like hospitals, commercial activities etc. In rural areas, the movement pattern of people is often short trips that include long walking distance to the transport hub or nearest boarding points. The fair is also adjusted with their limited purchase power, often limiting the private transport service providers using sub- standard and poorly maintained vehicles. These transports operate free of schedule causing long waiting times for the passengers.

Introducing an inexpensive fixed scheduled bus, minibus or shared taxis can be a solution for the absence of public transportation that can meet the mobility needs of rural people. However, this solution remains undo-able due to low purchase power of rural people, as revenue earned from the passengers is not sufficient for meeting the operation and maintenance cost of the service. Another solution can be encouraging the villagers to collectively invest in a community car(s) to as a commuter for the local

villagers. This approach is not practicable due to disagreements regarding the users, purposes and schedules.

An alternative approach is to focus on the causes of villager mobility [33] and reduce the frequency of transit. The villagers' need for transit is assumed to be based on a negative linear relationship between trip-frequency against distance-travelled. Also, there is a high frequency of short distances trips and a low frequency of long distance trips. Accepting this, a village community car can influence the trip-distance relationship by reducing the need for villagers to travel. The villager's primary need for medium to long distance trips are for welfare –health, education and shopping for goods not locally available [34]. It is, therefore, appropriate to reduce the need for medium to long distance travels as these trips are expensive for the villager in terms of financial cost and time. This is achieved by the community car bringing welfare services to villagers and using ICT to stabilize the quality.

The research problem of this study is to see we can provide a safe transport through an ICT based car-sharing system along with some other social services and its impacts in a rural environment [35], [36]. This is a villager centered transport approach because mobility comes to the user.

This study introduces an ICT based transport system called Social Services on Wheels (SSW) to improve the productivity of low-come villagers in unreached communities. The system is based on an IT model in which a transit vehicle is used to bring access to Healthcare, Education, Learning and Purchasing services to delivery points within villages. The SSW model has been tested in Bangladesh. We will discuss the findings regarding college bus service provided through this car sharing system.

3.2 Survey on Travel Behavior of Rural High School Girls

3.2.1 Study Profile

We observed a village in Bangladesh for two months by administering a survey among 83 households in a village and running an experimental car for rural senior high school level students. The experiment period was for 2 months (44 working days). Details of the survey profile given in Table3.1 and survey location is shown in Fig3.1.

Table 3.1: Experiment Profile

Attribute	Description
Locations	(a) Matlab (North) Upazilla, Chandpur District and; (b) Bedarganj Upzilla, Shariatpur District, Bangladesh
Area	(a) 190 km^2; $(b)262km^2$
Population	(b)170,000 people; (b)207,258 people
Number of households surveyed	83 ((a)41 in Uttar Matlab;(b) 42 in Bedarganj)

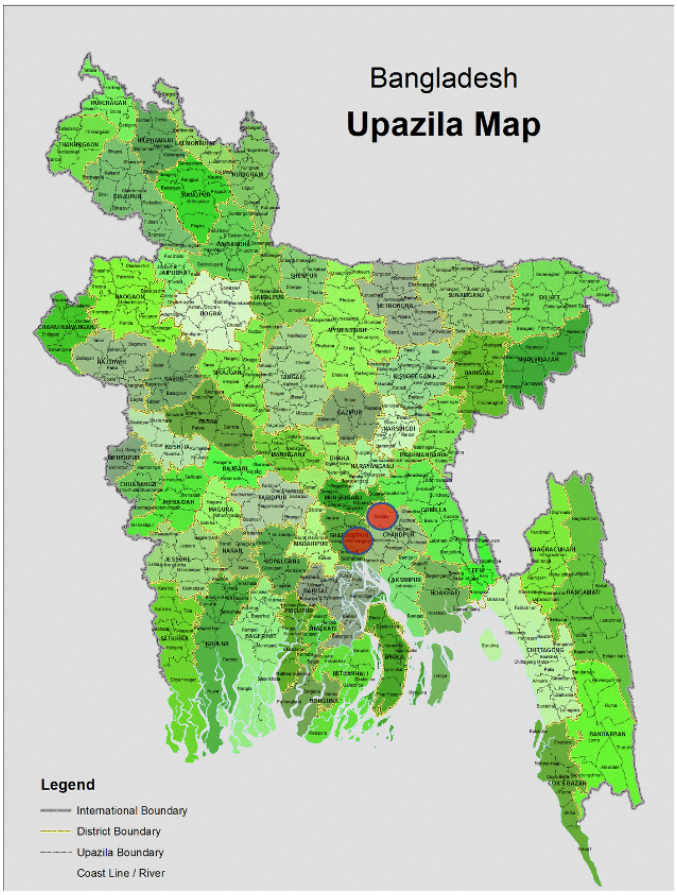


Figure 3.1: Survey locations of studied rural high school girl community (source: http://maps-of-bangladesh.blogspot.com)

3.2.2 Findings

We observed the following items: (a) Conventional transport (b) Commuting time and distance (c) Impact on education due to the irregular transport

The findings are described below:

(a) Conventional transportation in villages The transportation available in the villages are Tomtom, manual rickshaws, CNG driven auto-rickshaws, Van etc. Fig 1: Conventional Transportation in rural Bangladesh (a) Tomtom (b) Electric Vehicle (C) Van Fig 1 shows the most common mid-distance transports (Less than 20 km) in rural areas in Bangladesh.

Figure 3.2: Manual transports in rural areas - Rickshaw (left), Van (right)

Figure 3.3: Motor transport of rural areas - Tempo (left), Easy bike (right)

The poor road infrastructure, long distance for fuel stations, unavailability of vehicle maintenance support, entrepreneur to challenge a new transportation business, unseen business opportunity of the rural people for transport etc. were the main obstacles to introduce quality vehicle business in the rural areas. Considering the local demand and affordability, local entrepreneurs found their own way to introduce informal vehicles (Tomtom) to serve the community.

(b) Conventional commuting time and distance:

The distance to a college from home is on average 11 km which they commute in a complex way - they walk a significant part of the distance 2 at least two times and take the conventional transports available in the village for the rest of the distance. A significant reason for walking is that conventional transportation does not offer a stop near to their house. A college girl has to walk approximately 120 minutes to reach the nearest stop from her house. As a result, it requires a long commuting time, which is 180 minutes to 230 minutes on average a day. An average household with one female college student spends 1500 taka ($18 USD) per month (10% of their total monthly expenditure) for transport. Tomtom is a common transport for college girls to commute to college.

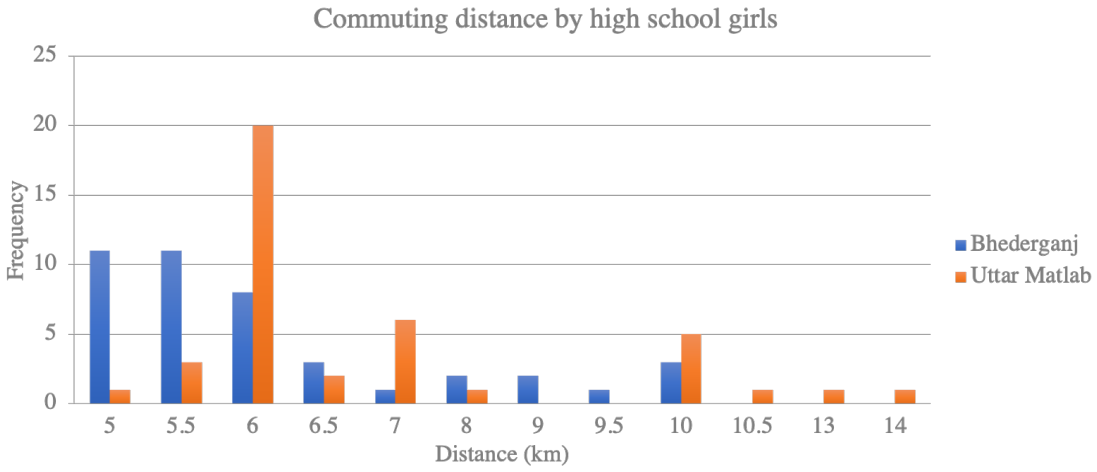


Figure 3.4: Travel distance of school commute by rural high school girls

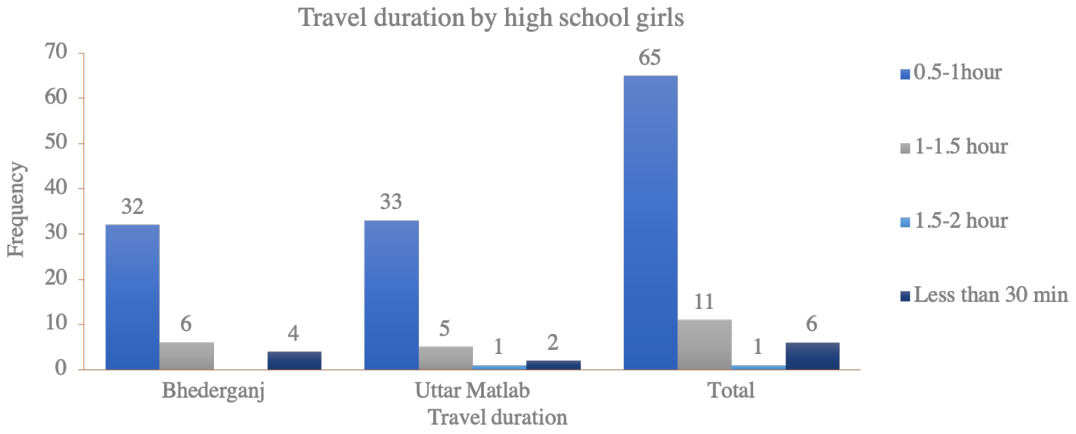


Figure 3.5: Travel duration of school commute by rural high school girls

(c) Conventional modes of rural transport and the effect on women

The gang rape and murder of a 23-year old female student in a bus in New Delhi in India in 2013 received international attention. Rural transportation is not safe either. Recently the incidents of eve teasing are increasing in a fast pace in Bangladesh. According to a survey by Bangladesh Women Lawyers' Association in 2010, 90% of girls aging from 10-18 are victims of public sexual harassment. Eve teasing is hard to prove with evidence as most of the time, it is verbal, not physical, and hard to identify the perpetrator.

As a result, girls do not feel comfortable sharing the congested Tomtom or other transports with male passengers. Girls do not want to share their sexual harassment stories with society as they are afraid of their parents may silently stop their education or be a social gossip.

These incidents highly affect girls' education. From our survey, we found that the absence rate of college girls is 20% a week due to inconvenient, irregular and unsafe transportation system. We also found that there was no comfortable transport for pregnant women.

3.3 Mobility Need of Rural High School Girl Community

Table3.2 summarizes the problems faced by SME employees while commuting by existing transport and their mobility needs for work commute.

Table 3.2: Problems with existing transport in Rural areas and Mobility needs of Rural High School Girls

Problems	Needs
Requires long distance walking to transport hubs. Dangers of eve-teasing and sexual harassment's during walking to transport hubs.	Less walking distance. Nearby boarding point.
No pre-defined schedule, operates when fully occupied its capacity. Absenteeism occurs due to bad and irregular transport.	Scheduled and guaranteed.
Crowded and uncomfortable vehicle, occurrence of groping, sexual harassment's.	Monitored, reserved seats, reliable co-riders (female students only).

The walking distance for rural high school girls is long and it comes with the dangers of being victims of eve-teasing, sexual harassment and sexual crimes. A nearby boarding point to their house can significantly reduce this risk and the physical burden of walking a long distance. Also, due to lack of a timetable of available transports, rural high school girls often causes late arrival at school, incomplete study and hamper educational achievements. Crowded vehicle causes discomfort and lack of risk of theft, in-vehicle harassment (e.g.: groping, teasing) and theft of belongings. A guaranteed, safe and comfortable vehicle dedicated to female students can be a solution for their transport needs.

3.4 Publication

1. Nuren Abedin, Jecinta Kamau, Hironobu Kitaoka, Hiroshi Okajima, Akira Fukuda, and Ashir Ahmed, "Providing safe and affordable transportation to reduce female student dropout: a case study on college girls in rural Bangladesh", IEEE Sys-

tems, Man and Cybernetics (SMC) 2016 Budapest, in 2016 IEEE International Conference on Systems, Man and Cybernetics, SMC2016-Conference Proceedings, pp: 4130-4134.

Chapter 4

Design of a Community Rideshare Model

This chapter explains the social and technical requirements of community mobility and introduces the system architecture of the proposed "Social Service on Wheels (SSW)" concept.

4.1 Social and Technical Requirements

The **Social requirements of a Community Rideshare** are listed as follows:

1. Accessibility: The travel should ensure access to social services such as access to education, healthcare, business, and recreation etc.
2. Affordability: The fare should be affordable
3. Safety and comfort: The journey should be safe and comfortable
4. Sustainability: The model should be financially sustainable

business etc. The fare should be affordable. The journey should be safe and comfortable.

The **Technical Requirements** are to ensure the followings:

1. The students or the employees of a company should arrive at school in time
2. Travel duration, as well as, distance should be as short as possible.
3. Number of hops should be minimum, Waiting time as well as transit time should be minimum
4. Number of accidents, theft, harassment should be zero

4.2 Components of SSW

Keeping all the above social and technical requirements in mind, the study proposed a community rideshare model, called Social Services on Wheels (SSW). The SSW architecture comprises the following major components:

1. Demography: Information about the users, their work or school location, residence location
2. Car Pool: Information about the registered vehicles with their capacity
3. Services: A list of social services designed for designated community
4. Scheduler: A scheduler for scheduling pre-defined and on-demand service schedules and routes

Figure 4.1 illustrates the model components and model design. The novelty of this model is that this model comes with services for both pre-defined and on-demand routes and schedules designed specifically for designated community mobility purposes.

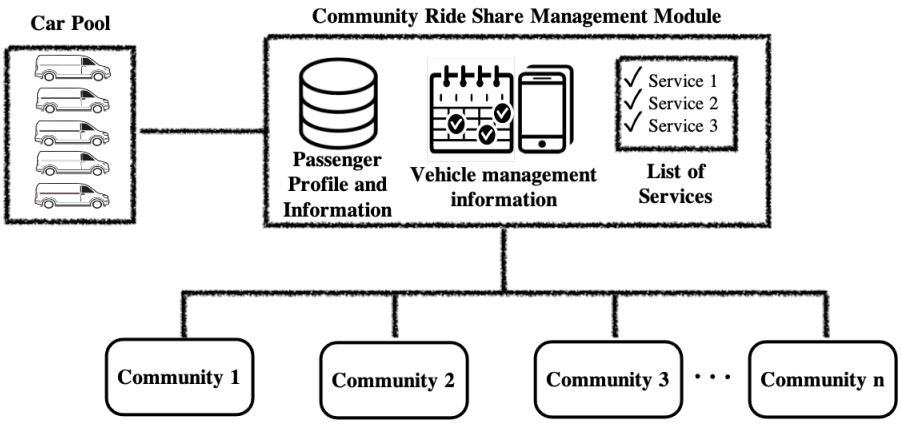


Figure 4.1: Proposed Social Services on Wheels model for community rideshare service

4.3 SSW for Different Communities

Communities have a different environment set up and mobility requirements. Therefore, the SSW model needs to be modified to the specific commuting facilitation requirements of designated communities. The three studied communities (an Urban SME community, an Urban Family community and a Rural Community in an emerging country) of this research are also very different in their environment set up and nature of mobility requirement. This research has proposed three modified models of SSW for these communities.

Three different modified versions of the SSW model have been designed for the three studied communities keeping the focus of serving the mobility needs of each community. The three modified models are which are discussed in the dedicated chapters:

1. SSW for Urban SME Community
2. SSW for Rural Community

Elaborated description of these models are given in the designated relevant chapters.

4.4 Publication

1. Nuren Abedin, Kenji Hisazumi, and Ashir Ahmed, "Affordable Rideshare Service for female urban corporates in developing countries: A case study in Dhaka, Bangladesh", 21^{st} International Conference on Human-Computer Interaction (HCII-2019), Orlando FL, Springer Communication in Computers and Information, volume:1088, pp:283-289.

Chapter 5

Social Experiments and Evaluation of SSW

This chapter describes the social experiment of the SSW model in two communities - one urban SME community and one rural high school girl community. Details of the experiment profiles, methods and findings are discussed in following sections.

5.1 SSW for Urban SME Community

SME community comes with three types of commuting: 1. commuting by SME employees for workplace and 2. commuting by employees to execute company errands. Communing by employees for workplace and 3. on-demand travel needs during work hours or holidays. (type 1 SME commuting) has pre-defined travel attributes: this travel pattern is with a fixed schedule to a fixed destination, even using some pre-defined routes and modes. Type 1 SME commuting requires a work commuter for two times of a day- in the morning and the evening. There is a big gap of 8-9 hours in between these two commutes.

Commuting for executing company errand (type 2 SME commuting) can consist of

both pre-defined pattern and on-demand pattern. Companies that share same office location, usually use some common facilities like banks, postal services, municipal and regulatory offices, office supplies procurement places, food purchase places etc. Commuting to these facilities incur during office hours which is common for the SME companies. There are some on-demand errands for companies as well that comes with irregular schedule, destination and routes. In the Proposed SSW SME community rideshare model, three services are specifically designed to accommodate the type 1 and type 2 commuting patterns. SME employees also has occasional commuting needs for holidays and weekends which is a non-work travel need for SME community (type 3 commuting). Fig 5.1 illustrates the model attributes discussed.

- **SSW work commuter service** in the morning and evening for type 1 employees work commute pattern
- **SSW corporate errand shuttle bus** for pre-defined and redundant SME commutes of type 2 commuting pattern
- **On-demand Office Car** for type 2 on-demand commuting pattern during work days, and **On-demand holiday car rental** during holidays and weekend for type 3 commuting.

5.2 Social Experiment of SSW for Urban SME

This section discusses a pilot study that has been carried out to measure the differences SME employees experience between work commute patterns using the existing transport modes and work commute patterns with SSW work commuter service. A survey on 314 employees in 20 SME to understand their mobility needs, attitude towards rideshare services, their commuting pattern including time, cost and distance. Based on their location data, available routes, we designed an experimental environment to run

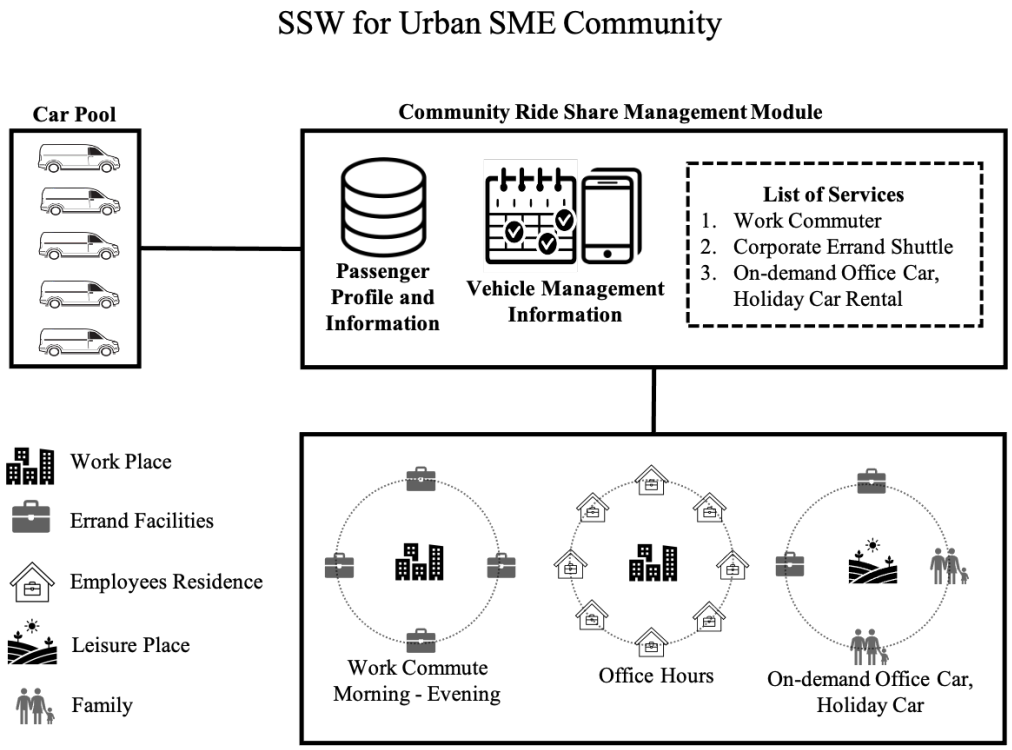


Figure 5.1: SSW rideshare model for SME Community

two cars in two different routes with two different sets of passengers. The duration of the pilot was for two months for 18 employees from different SME. At the end of the pilot, we surveyed on the passengers to know the mental status, time efficiency, safety issues and their desired fare for this service. Details of of the pilot experiment method and findings are discussed in the following sections.

5.2.1 Urban SME Experiment: Experiment Profile

The study on understanding travel behavior of SME employees collected data on employees' commuting pattern, mode, expense, and attitude towards using rideshare to work among 314 people from 20 SMEs located in Grameen Bank complex, in Mirpur, Dhaka, Bangladesh. An experiment was conducted piloting two-10-seat cars in Dhaka that aimed to find out the performance of SSW for Urban SME community. Details of

the experiment profile is given below:

Table 5.1: Experiment Profile of SSW for SME Community

Item	Detail
Objective	Compare the advantages of SSW over existing transport
Location	Grameen Bank Complex, Mirpur-1, Dhaka, Bangladesh
Number of participants	18 (selected from 314 survey respondents)
Collected data type	Travel duration, walking requirement, waiting time, required hops, operational data
Data collection method	User feedback survey, GIS tracking device information
Duration	2 months (44 working days)
Type of vehicle	10-seated-van (Toyota Hiace)
Number of vehicles	2
Number of Routes:	2

(a) Participation Selection

The participants of this experiment were selected through a 2-step-process- Step1: filtering from the the potential participants who participated in the travel behavior survey; Step2: Contacting each potential participants in for understanding their willingness to participate in this experiment.

The filtration process is illustrated in Fig 5.2. There were two conditions in the filtration. The first condition was to filter out the survey respondents (employees) unwilling to use a rideshare service for work commute. The second condition was to filter survey respondents (employees) who live within a distance less than 3km from the experiment location. 3km distance range was found to have most number of non-motor mode users (e.g.: walking, rickshaw, bicycles) live within and hence were filtered out for this experiment. Eighteen participants were selected through this selection process among whom 10 were male and 8 were female.

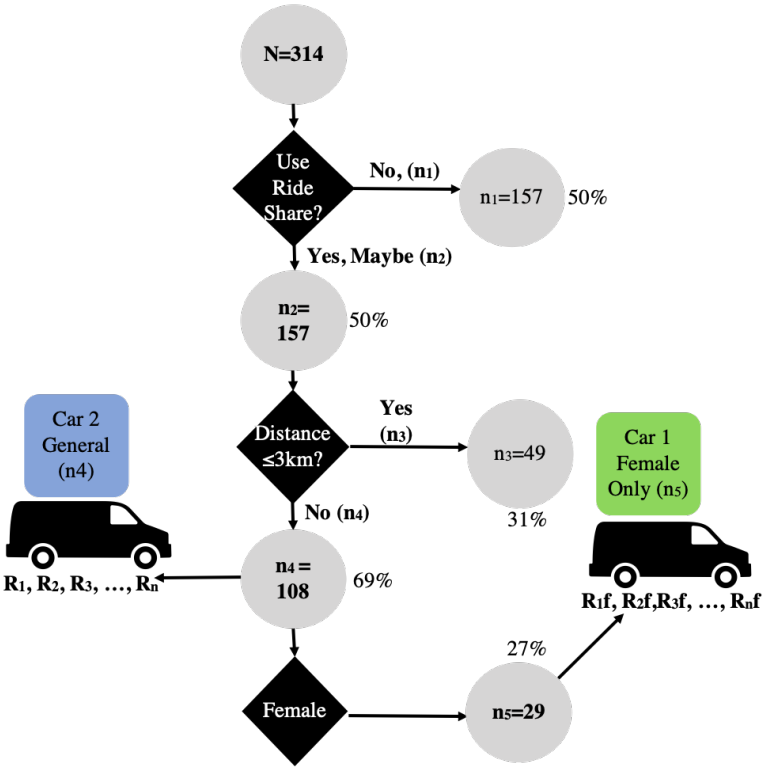
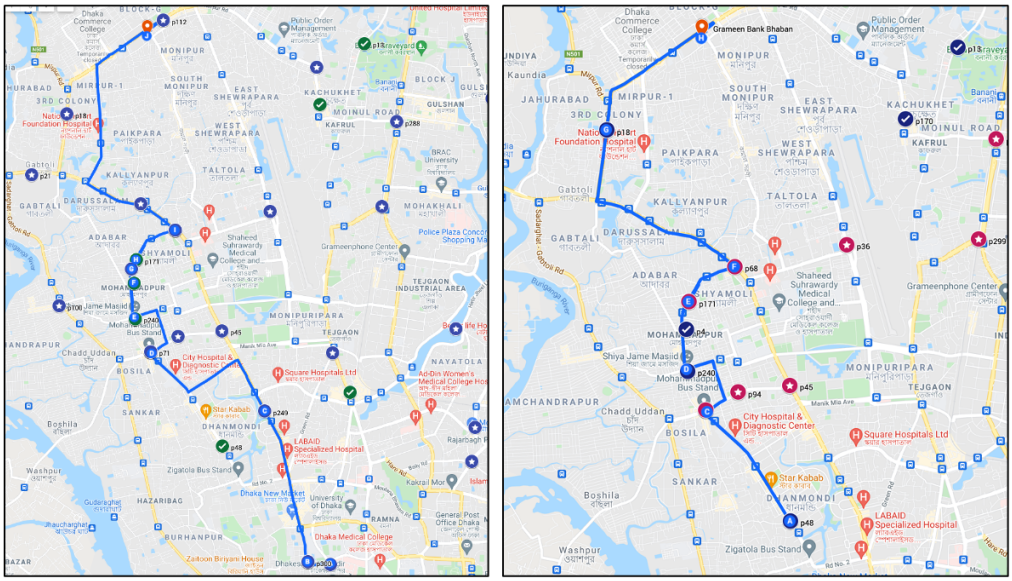


Figure 5.2: Process of selecting participants for the pilot experiment of SSW for Urban SME community

(b) Route Selection

The routes for this experiment were selected maximum number of willing employees. Boarding point information were inserted in Google map to determine possible routes and the routes with most number of employees willing to participate in the experiment. Fig 5.3 shows the two chosen routes on Google map.



Route1: Buet Campus to Grameen Bank Complex

Route2: Dhanmondi to Grameen Bank Complex

Figure 5.3: Two routes of the experiment of SSW for Urban SME Community

5.2.2 Urban SME Experiment: Findings

The findings of the experiment are described below:

(a) Finding 1: Twelve participants (67%) among eighteen reported to have more work time while using SSW service. On the contrary, 5 participants (28%) said they had less time to work. 50% participants said to have more personal time and 33% participants less personal time while using SSW service. Fig 5.4 shows this findings.

It was found that participants in average reported to have 23 minutes extra work time and 34 minute extra personal time when they traveled by SSW to work (5.5).

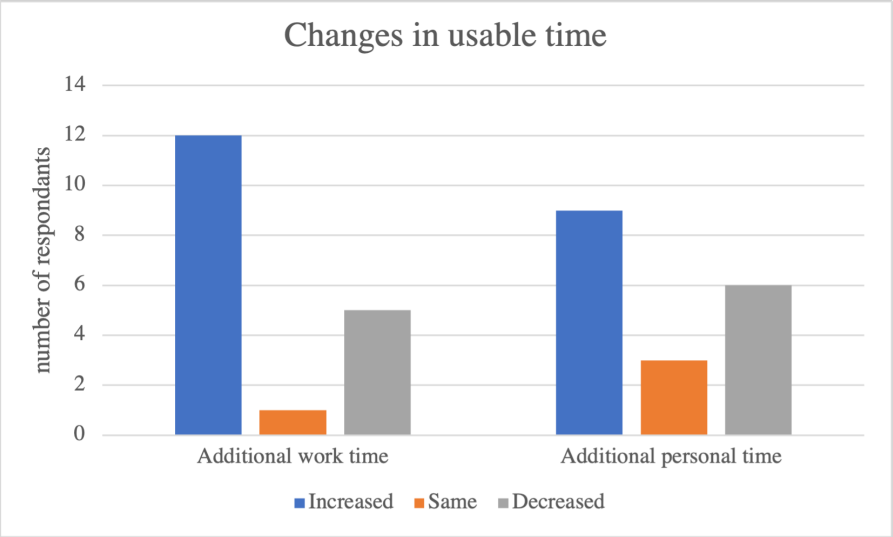


Figure 5.4: Participants response regarding changes in additional work and personal time between using existing transport modes and RDS as a staff bus for work commute

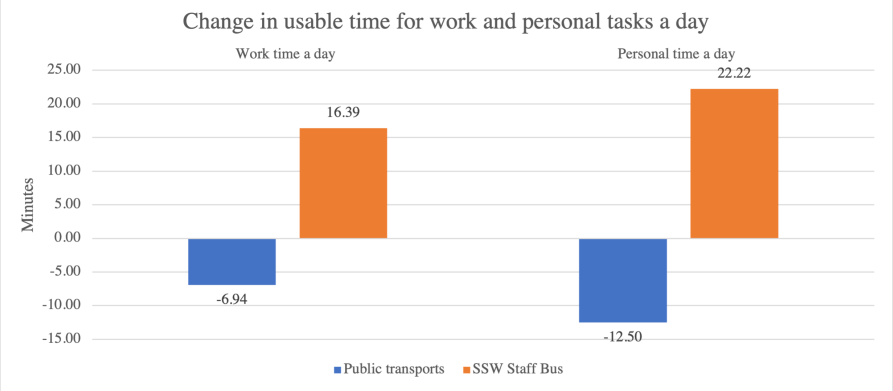


Figure 5.5: Changes in available work and personal time between using existing transport modes and RDS as a staff bus for work commute

(b) Finding 2: Participants were asked about their travel experience by SSW Staff Bus. Participants said the number of unpredictable incidents (such as losing belongings, robbery, theft), unwanted incidents (e.g. reckless driving, crowded vehicle) decreased significantly. Participants reported to remain alert the whole time while using public transports, but this phenomenon significantly decreased while using SSW Staff bus.

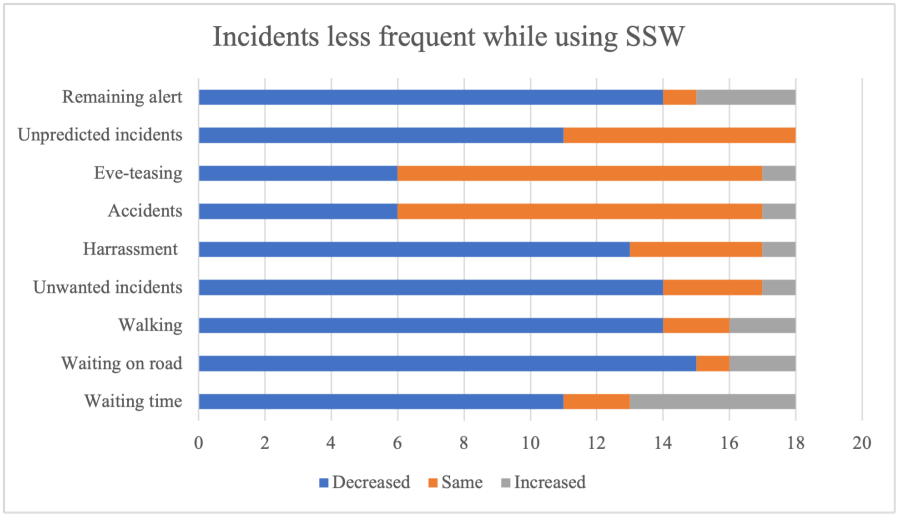


Figure 5.6: Changes in frequent incidents between using existing transport modes and RDS as a staff bus for work commute

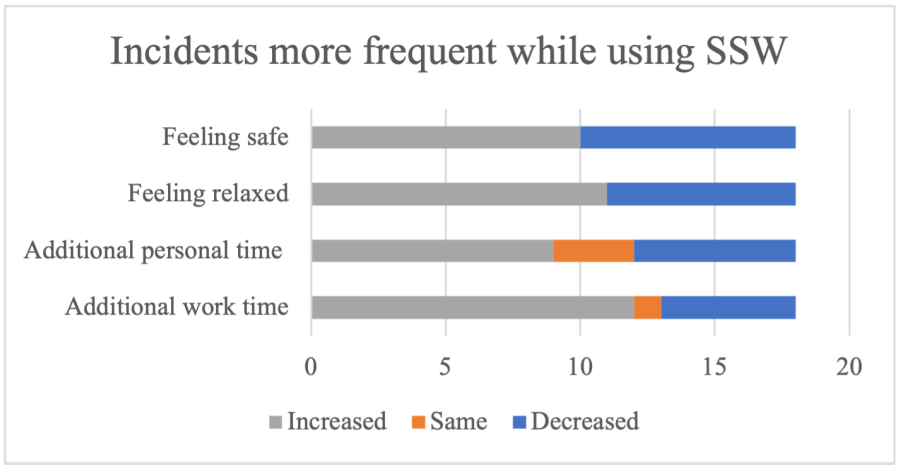


Figure 5.7: Changes in feeling of travel safety between using existing transport modes and RDS as a staff bus for work commute

5.2.3 Urban SME: Interpretation of the Findings

Employees have a fixed time to arrive work and leave work. Majority of the participants have reported to that with SSW Staff bus service, their waiting time on road to avail a transport has decreased comparing to that for public transport. This can add up to 460 minutes (7.7 hours) extra a month for work and 680 minutes (11.3 hours) extra

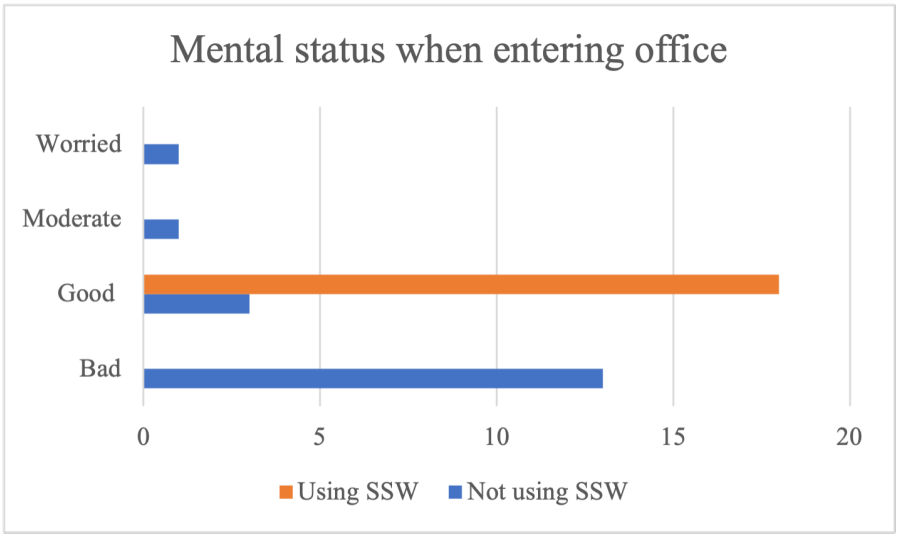


Figure 5.8: Changes in available personal time between using existing transport modes and RDS as a staff bus for work commute

for personal work for employees.

We also found that SSW could enhance travel safety by reducing the possibility of accidents, unwanted incidents (robbery), harassment etc. to zero. Participants re-ported to reach in good mental status when used SSW to work.

In this chapter, we described the need for designing a rideshare system for SME employees. We demonstrated the findings from surveys and pilot of this model and discussed the affordability aspect and benefits of this model. Financially, using SSW Staff bus would be more expensive than using public transportation, but definitely cheaper that using the commercial rideshare services available. However, this service enhances benefits for employees by providing more time for work and personal time, increase personal safety and work productivity by providing safe and comfortable travel experience every day. Further study is required to develop the best route selection algorithm where the passengers are picked up from multiple sources but dropped off at a single point and vice versa. The same model can be used for rural areas in developed countries like Japan where people live in a small community but the population density is low.

5.3 Summary: Experiment in Urban SME Community

To study the SME community mobility pattern, this research investigated the travel patterns of 314 SME employees to design a financially viable ridesharing service for them. It reports their travel behavior in terms of the mode of transports, distance, and travel expense pattern. It also investigated their attitude towards using a rideshare service for work commute. Based on the findings on their travel attributes, this research recommends a set of criteria and classifies the potential and non-potential users of a rideshare service to workplace. We recommend that employees living within a distance of 2.5 15 km, currently using motorized vehicle for work commute, who can spend $40 a month and agree to mutually determined commuting schedule are the most potential users for an effective and financially sustainable rideshare service. These findings can be used by commercial private transport providers for designing a work commuter "pickup and drop-off" service. Also joint-transport initiatives can be formed among a group of SMEs who are enthusiastic about providing safer and affordable work commute for their employees. The same methodology can be used to design rideshare services for school children, college or university students. We are working on scheduling the rideshare service to estimate the pickup time and pick up points for each passenger. This model targets SMEs in the same vicinity. We assume that the working time for all the SMEs are the same which is a hard assumption. People with different working time will require multiple vehicles. Scheduling for them will be a challenge both financially, technically and socially.

5.4 Social Experiment of SSW Rural School Girl Community

High school girls in rural areas of Bangladesh travels 11km in average and a big portion of this distance requires walking to the transport hub. A ride choice that would

be available for pick up near house can reduce a lot of issues caused by long distance and unsafe walking to school. The pattern of school commute for rural girls has similarity with the pattern of SME employees. In the morning girls travel from multiple sources to single destination and vice versa in the evening. Unlike emerging urban areas, congestion is rare, making it faster for transport service provider to pick up high school girls from near their residence.

SSW for Community contains a school bus service for these high school girls matching with the educational institution's schedule. In the idle time, this car is designed to provide multiple other services like Healthcare service, goods delivery service, blood grouping service, internet cafe service and emergency vehicle service for the designated rural community. Fig 5.9 illustrates the service model.

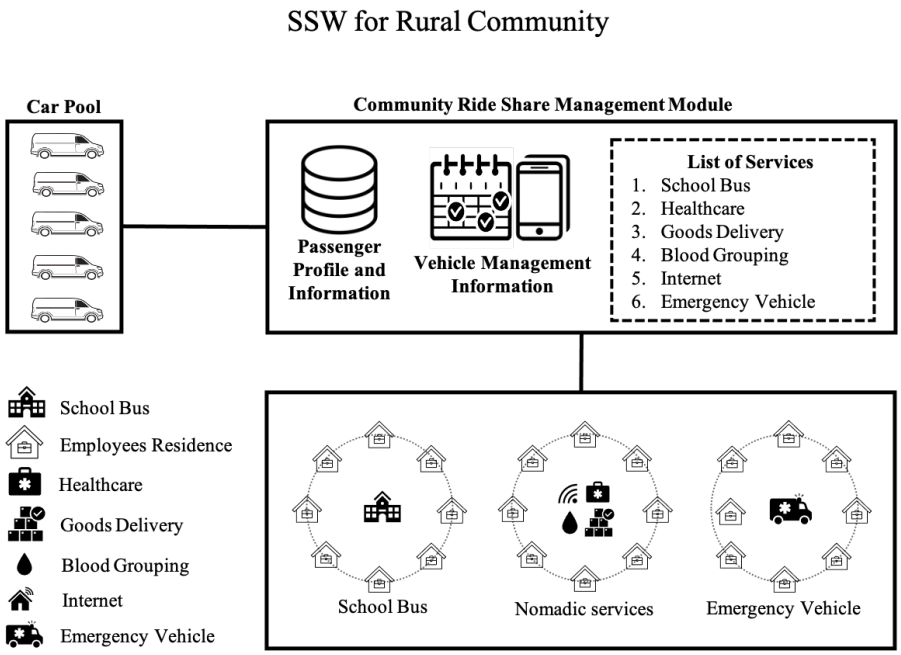


Figure 5.9: Proposed SSW rideshare model Rural Community

5.4.1 SSW Rural: Study Profile

The location of this study was chosen from one of the studied villages during survey for understanding travel behavior of rural high school girls - "Uttar Matlab" in Chandpur, Bangladesh. The experiment was piloted for two months. Total effective days were 44 days excluding the weekly holidays. The participants of the pilot were rural high school girls from 41 households who participated in the survey in Uttar Matlab. The rural high school girls were provided with a school bus service. A female driver was employed for SSW. The SSW for rural community had its daily and weekly schedule. SSW picked up female students from the predefined pick up points and drop them to the college. With an aim to check the technical requirement for the model sustainability, other services were scheduled and provided outside the time of school bus service. Details of experiment profile is shown in Table5.2 and the experiment location and route is shown in Fig5.10.

Table 5.2: Experiment Profile of SSW for Rural High School Girl Community

Item	Detail
Objective	Compare the advantages of SSW over existing transport (travel duration, walking requirement, waiting time, operational sustainability
Location	Uttar Matlab, Chandpur, 45km west of Capital City Dhaka, Bangladesh
Participants	41 households
Duration	2 months (44 days)
Type of vehicle	10-seated-van (Toyota Hiace)
Number of Vehicle	1
Number of route	1
Data collection method	User feedback survey

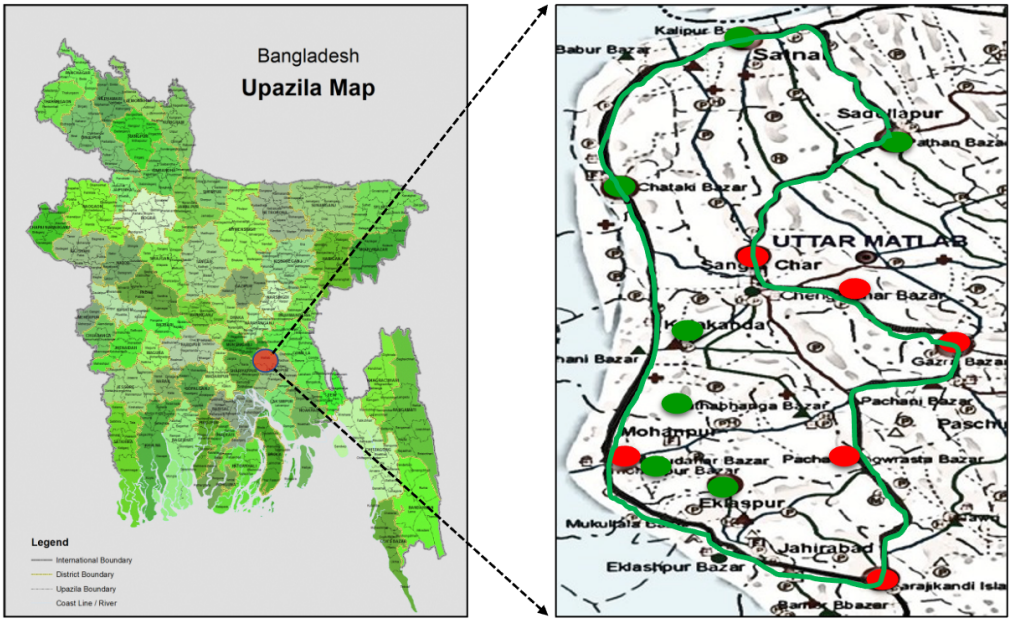


Figure 5.10: The location and route of SSW for Rural High School Girl Community Experiment (Source: http://maps-of-bangladesh.blogspot.com)

5.4.2 SSW Rural: Findings of the Pilot Experiment

(a) Advantages of the college bus service

SSW had significant impacts on a college girl's daily life. The information is illustrated in the table below: Table II: Comparing conventional transport and local transport

Table 5.3: Comparing conventional transport and local transport

Items	Existing Transport modes	RDS School Bus
Time	180-230 Min	100 Min
Walking	120 Min	10 Min
Lifestyle	No time for breakfast	Can have breakfast
Healthcare	Dizziness, headache. muscle pain, numbness	No such symptom
Household work	Cannot help parents	Spent saved time
Home work time	Less	Additional hours

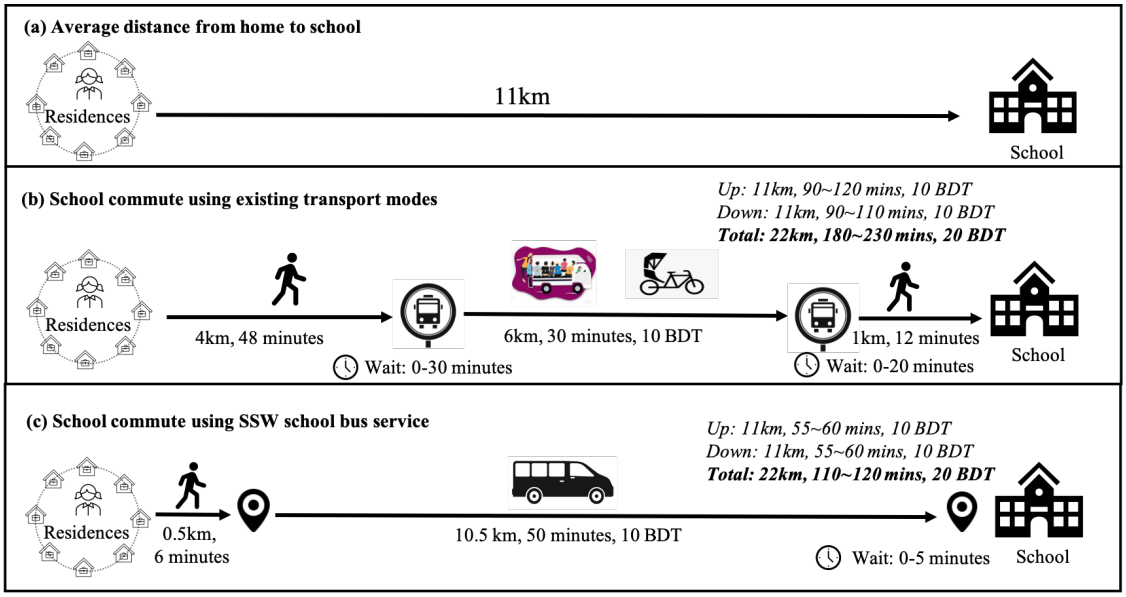


Figure 5.11: Advantages of using RDS as a school bus service

It takes 90 to 120 minutes for a female student to commute to and from her school or college. Although the time reduces to 55 to 60 minutes when she uses the SSW college bus service. A female student can save 35 to 60 minutes per day from her traditional commuting time to school or college. An average college girl spends 230 minutes (in maximum) for a round trip journey to college including the waiting time, risk of the irregularity of the transport. But she spends 110 to 120 minutes by SSW college bus service. As a result, she can save 90 to 110minutes per day using SSW college bus service. The scenario is shown in the figure below:

(b) Popularity aspect

College bus performance: Most of the time, the car was full (11 students per trip) on the way to college. Students with different returning schedule did not use the car. We tried monthly, weekly, daily basis payment methods. Students preferred payment on daily or weekly basis to avoid the journey for unmatched schedule. However, the most popular service was blood grouping that belonged to the healthcare service. And this service has 107% cost coverage. This will not be a recurring revenue generating service.

But it can popularize other SSW services.

(c) Sustainability aspect

The revenue from a college bus service is insignificant. As a result, the revenue from this service is not sufficient enough to sustain the car sharing system. The share of revenue from school bus service for rural high school girls is only 12.845 (shown in Fig5.12. largest revenue share was from healthcare service (40.57%) among all six services.

Only 52% of total operational cost could be covered by the revenues generated from each service. Only blood-grouping service could cover its operational cost. Healthcare service was second in this rank covering 81% of its costs and school bus could cover only 63% of its operational cost. Fig5.13 shows this distribution.

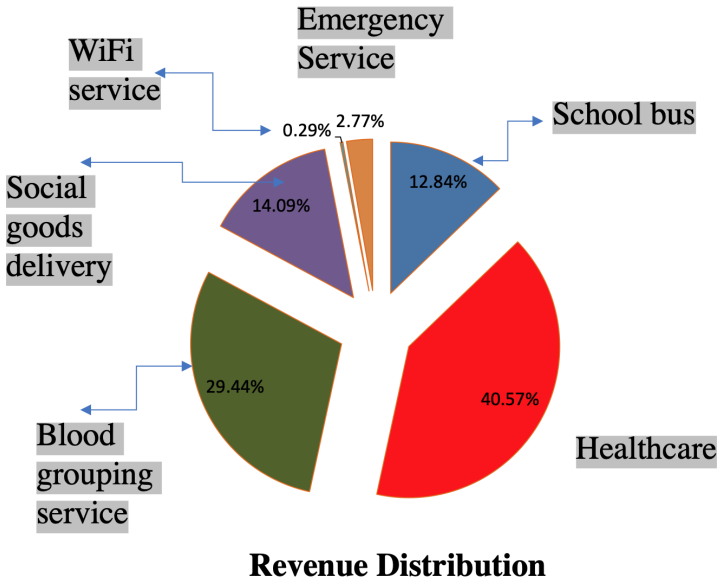


Figure 5.12: Revenue distribution from different services

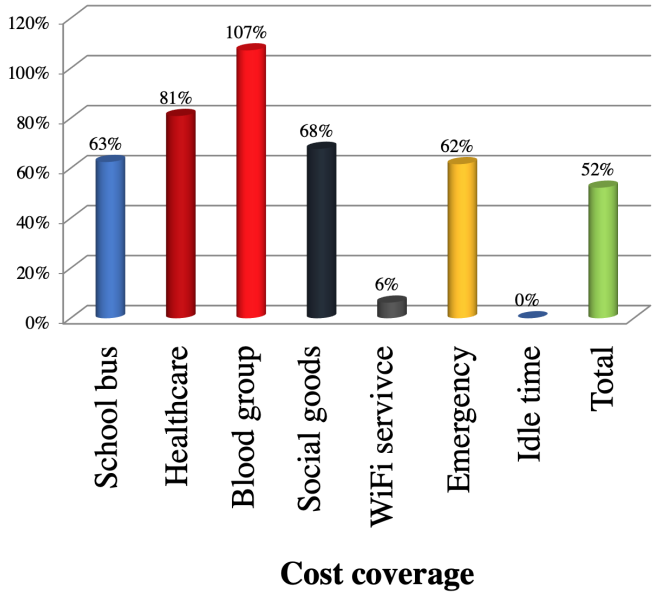


Figure 5.13: Adding different services to maximize resource utilization for service sustainability

(c) Resource Utilization

The total operation time of a car is only 10 hours per day. We can maximize its utilization by introducing the on-demand emergency service raised by the villagers. The call center for remote healthcare support (most expensive cost component, 35% of the total cost) remained idle for 60% of its operating hours. This cost can be shared if we add more community cars in separate sites.

(d) Reaction from the local community

We provided the services only to the female students and passengers. Male passengers, especially the college students felt discriminated and wanted similar services for them too. By one car, we could serve only 22 students in one route. Students from other routes also demanded the service.

However, SSW became a source of anger of the local Tomtom drivers. They are concerned about losing their own business. The same reaction came from the local doctors and social good sellers. The community leaders need to be acknowledged before we start

a similar service. A portion of the people who are accustomed to receive social services from different NGOs and philanthropic organizations for free of cost, was expecting the same from SSW. Offering the service in a business way for longer period of time can change this attitude.

5.5 Summary: Experiment on Rural High School Girl Community

The study summarizes the nature of transportation and their needs in the rural community in Bangladesh. it was found that a school bus service can benefit an adolescent rural high school girl regarding time, studies and health by reducing significant portion of walking distance, duration and physical strain and reducing the risk of being exposed to eve-teasers and sexual harassment predators. Also we have shown that having one service for a car is not a good strategy to sustain that service. The car can provide other social services to generate revenues and sustain a big social impact through it. We have shown that a quality vehicle with 6 social services can cover 52% of its operational cost. The operational cost can be reduced by proper utilization of ICT and maximize the income by providing more social services during the car's idle time. We have also found out that the need for more convenient transports is highly demanded by the villagers. However, college bus service schedule management is another challenge here as the college schedule for different students varies. We need to work on a feasible solution that lets them reserve their seat on their demand.

5.6 Overall Social Impact and Discussion

A community rideshare can be designed. An individual in a emerging country may not afford a car, but a community can. An old person in an advanced country can afford a car but is not encouraged drive. A community rideshare service can serve both their

mobility needs. The proposed community rideshare model work as a subscription based model. The users will not have to own or manage any assets like an expensive vehicle. They will just pay for the service. This will increase the access to quality mobility for low-middle income people at the same time solving lot of unspoken social issues.

The study has made it clear that there is a big social dependency on transportation. A father in a rural area in developing country feels insecure to send his adolescent girl to school because the road to school is not safe and finally decides to settle a marriage for her. The girl drop out rate increases. Similar case is witnessed in other developing countries in Asia and Africa. A door to door school bus service can strengthen the father's mind to send his daughter to schools.

Public transportation is affordable for the SME employees in urban areas. However, in most of the developing countries the public buses do not follow any schedule, the employees either arrive too early or arrive late at office. Thus, productivity at work is hampered. The proposed community rideshare proves that the delay can be almost reduced to zero. Also as the SSW provides door to door commute service, number of hops during the trip becomes zero, the transit time, waiting time also become zero. Thus, an employee can save travel time and invest the saved time at work or at home to increase productivity.

Rideshare policy is not mature yet. This work provides an opportunity to create evidence to convince the policymakers.

5.7 Publications

1. Nuren Abedin, Kenji Hisazumi, and Ashir Ahmed, "Affordable Rideshare Service for female urban corporates in developing countries: A case study in Dhaka, Bangladesh", 21^{st} International Conference on Human-Computer Interaction (HCII-2019), Orlando FL, Springer Communication in Computers and Information, vol-

ume:1088, pp:283-289.

2. Nuren Abedin, Jecinta Kamau, Hironobu Kitaoka, Hiroshi Okajima, Akira Fukuda, and Ashir Ahmed, "Providing safe and affordable transportation to reduce female student dropout: a case study on college girls in rural Bangladesh", IEEE Systems, Man and Cybernetics (SMC) 2016 Budapest, in 2016 IEEE International Conference on Systems, Man and Cybernetics, SMC2016-Conference Proceedings, pp: 4130-4134.

Chapter 6

Conclusions and Future Work

This research introduced a new concept of "community rideshare" and proposes a model, called SSW (Social Services on Wheels). Two communities (one in urban and one in rural with different demographics) in Bangladesh were studied, their travel behavior as well as the performance of SSW in these communities are presented.

First, this research carried out two separate surveys in two different communities to understand their daily mobility needs and their current travel behavior. The communities are: (1) Urban SME (n=314) and (2) a rural community (n=83 households). Some of the findings of the survey are previously known but the study lists the consequences and root causes which become important element for designing the proposed SSW model. The common characteristics are: (a) Short distance but long travel duration due to multiple transfers, longer route, waiting time and congestion; (b) Irregularity of transport causes uncertainty of transport availability and failing to arrive destination on time with consequences of less productivity and bad impression; (c) Unsafe and insecure transports cause accidents, occurrence of incidents like theft, sexual harassment etc. The unsafe route and transport facilities ultimately cause problems like dropouts of high school girls in villages. Bad transport system also negatively impact SME employees work performance by causing lateness in arrival and irritating mental status.

Second, this study proposes an SSW model to meet the travel needs and piloted the model in two different areas to collect experiment data and evaluate its performance.

Third, two social experiments were conducted in two communities (a) urban SME community (2 months, 20 SMEs in one complex, two 10-seated-vans with 18 selected employees on two routes) and (b) rural high school girl community (2 months, 83 households, one 10-seated-van). Experimental data e.g., pickup time, drop off time, pick up and drop off points, vehicle movement and pause duration were collected by using our own developed software system and Google APIs. The collected data were analyzed to understand both qualitative and quantitative travel behavior e.g., increased travel safety, reduced travel duration, increase cost performance and increased comfort.

As SSW offers door to door service, number of hops become zero, the waiting time in the road can ideally be saved 100%. The benefits of SSW for urban SME community are reduced number of hops and reduced waiting time, and increased safety and comfort; the cost performance was satisfactory. SSW for rural high school girls reduced walking distance almost 10 times (from 5km to 0.5km) and 70-110 minutes of walking, provided safer and comfortable travel environment, reduces risk of sexual harassment and eve-teasing during school commute. In rural areas, apart from school bus service, more services (e.g., healthcare, goods delivery, emergency car, internet service etc.) were required to designed for financial sustainability.

Future work of this research would be identifying the criteria of potential users of SSW service in different communities. An extension of SSW service for Urban family mobility is also in consideration. This model can also be applied in rural areas of developed countries where transportation system slacking due to depopulation. Studying its application in such areas would also create valuable knowledge.

Bibliography

[1] D. Perez-Barbosa and J. Zhang, "Transport-based social exclusion in rural japan: A case study on schooling trips of high school students," *Social Inclusion*, vol. 5, no. 4, pp. 235–250, 2017. 1

[2] N. Fukui, M. Chikaraishi, and A. Fujiwara, "A collective household model of driving cessation of older adults," in *Mapping the Travel Behavior Genome*. Elsevier, 2020, pp. 435–453. 1

[3] L. Zhang, J. Zhang, and D. P. Barbosa, "Impacts of built environment and travel behavior on high school students' life satisfaction and future life plans: A preference-based case study in depopulated areas of japan," in *Mapping the Travel Behavior Genome*. Elsevier, 2020, pp. 413–434. 1

[4] B. Du, Y. Yang, and W. Lv, "Understand group travel behaviors in an urban area using mobility pattern mining," in *2013 IEEE 10th International Conference on Ubiquitous Intelligence and Computing and 2013 IEEE 10th International Conference on Autonomic and Trusted Computing*, 2013, pp. 127–133. 1

[5] A. Millard-Ball, *Car-sharing: Where and how it succeeds*. Transportation Research Board, 2005, vol. 60. 1

[6] P. Okun. Beyond uber: Your guide to ridesharing apps around the world. 2

[7] L. Rayle, S. Shaheen, N. Chan, D. Dai, and R. Cervero, "App-based, on-demand ride services: Comparing taxi and ridesourcing trips and user characteristics in san francisco university of california transportation center (uctc)," *University of California, Berkeley, United States*, 2014. 2

[8] M. A. AISBL. (2017) Guideline and recommendations to create the foundation the foundation for a thriving maas system. 2

[9] Z. T. Falconer R. and F. M, "Mobility-as-a-service: The value proposition for the public and our urban systems," 2018. 2

[10] M. I. H. Nasrin Akter, Faiza Noshin Rahman. Transforming ride-sharing into sustainable business. 2

[11] M. Vanderschuren and J. Baufeldt, "Ride-sharing: A potential means to increase the quality and availability of motorised trips while discouraging private motor ownership in developing cities?" *Research in transportation Economics*, vol. 69, pp. 607–614, 2018. 2

[12] "Cities on the move: a world bank urban transport strategy review," 2002. [Online]. Available: https://openknowledge.worldbank.org/bitstream/handle/10986/15232/24910.pdf?sequence=5 2, 5

[13] N. Abedin, J. Kamau, H. Kitaoka, H. Okajima, M. Okada, A. Fukuda, and A. Ahmed, "Providing safe and affordable transportation to reduce female students dropout: A case study on college girls in rural bangladesh," in *2016 IEEE International Conference on Systems, Man, and Cybernetics (SMC)*. IEEE, 2016, pp. 004 130–004 134. 2

[14] H. K. A. A. Abedin Nuren, Kamau Jecinta, "Ride-share in compromised transport resources area areas of japan: Case studies in itoshima city, yame city and tango

town," in *in proceedings of The 2nd International Conference on Healthcare, SDGs and Social Business 2018*, 2018, pp. 49–52. 2

[15] S. M. Kamal and N. A. Ahsan, "Uber-pathao'ride-share's impact on dhaka," *The Financial Express.[online] Available at: https://thefinancialexpress. com. bd/views/uber-pathao-ride-sharesimpact-on-dhaka-1524842540 [Accessed 26 Oct. 2019]*, 2018. 3

[16] L. Olsson and M. Thynell, *Bangladesh Road Transport Corporation (BRTC) Bus Project in Dhaka*. Sida, 2006. 3

[17] A. Poole, "How-to notes: political economy assessments at sector and project levels," *Washington, DC: World Bank*, vol. 2, 2011. 3

[18] D. Katz and M. M. Rahman, "Levels of overcrowding in bus system of dhaka, bangladesh," *Transportation research record*, vol. 2143, no. 1, pp. 85–91, 2010. 3, 5

[19] M. N. Sakib and M. H. Mia, "The ride-sharing services in bangladesh: Current status, prospects, and challenges," *European Journal of Business and Management*, vol. 11, no. 31, pp. 41–52, 2019. 5

[20] M. Jahan, "Factors affecting customer satisfaction of the ride-sharing industry in bangladesh," 2019. 5

[21] M. S. Mannan, "Road accidents in metropolitan dhaka, bangladesh," *IATSS research*, vol. 23, no. 2, 1999. 5

[22] M. S.-U. Rahman and K. Nahrin, "Bus services in dhaka city-users' experiences and opinions," *Journal of Bangladesh Institute of Planners ISSN*, vol. 2075, no. 4, p. 9363, 2012. 5

[23] M. Shefali, "Study on gender dimension in dhaka urban transport project," *Wash-*

ington DC: The World Bank (online under www. worldbank. org/gender/transport), 2000. 5

[24] N. Abedin, J. Kamau, M. I. Hossain, R. I. Maruf, A. Fukuda, and A. Ahmed, "A case study to design a mobility as a service model for urban female corporates to improve their work performance," in *TENCON 2017-2017 IEEE Region 10 Conference*. IEEE, 2017, pp. 1445–1450. 6

[25] M. Tarek and S. Amit, "A closer look at the sharing economy, global ridesharing and ridesharing in bangladesh," *ULAB thought leadership article, Centre for Enterprise and Society*, 2019. 6, 25

[26] BRTC. Internet subscriber of bangladesh. 7

[27] S. Shahidul and A. Karim, "Factors contributing to school dropout among the girls: A review of literature," *European Journal of research and reflection in educational sciences*, vol. 3, no. 2, 2015. 7, 33

[28] United nations sustainable development goals. [Online]. Available: https://sdgs.un.org/ 32

[29] Unesco global partnrship for girls' and women's education. [Online]. Available: http://www.unesco.org/eri/cp/factsheets_ed/ET_EDFactSheet.pdf 32

[30] N. Aggrey, T. Oliver, and B. Stella, "Academic performance of female students enrolled under pre-entry programme at the university of dar es salam," *Journal of Emerging Trends in Educational Research and Policy Studies (JETERAPS)*, vol. 5(3), pp. 288–293, 2014. 32

[31] J. A. Amina, "Challenges faced by girls who dropout from senior high school: the voices of sixty dropout girls in the upper west region of ghana," *International Journal of Humanities and Social Science*, vol. 5, no. 6, p. 1, 2015. 32

[32] Y. Hirakawa and F. No, "Identifying causes of drop out through longitudinal qualitative analysis in rural cambodian basic schools," *Journal of international Development and Cooperation*, vol. 19, no. 1, pp. 25–39, 2012. 33

[33] J. Kamau, A. Reberio-Hargrave, E. Abdullah, I. Rafiqul, K. Nobuhara, H. Okajima, and A. Ahmed, "Villager centered transport system in unreached communities," in *2014 IEEE International Conference on Systems, Man, and Cybernetics (SMC)*. IEEE, 2014, pp. 1893–1897. 34

[34] D. Hu, "Trade, rural–urban migration, and regional income disparity in developing countries: a spatial general equilibrium model inspired by the case of china," *Regional Science and Urban Economics*, vol. 32, no. 3, pp. 311–338, 2002. 34

[35] C. Prahalad, *The Fortune Ad the Botton of the Pyramid: Eradicating Poverty Through Profits*. Wharton School Publishing, 2006. 34

[36] R. Carruthers, M. Dick, and A. Saurkar, "Affordability of public transport in developing countries," 2005. 34

Appendix A

Urban SME Employee Survey Questionnaire

A.1 SME Employee Work Commute Survey

Ride sharing survey (Staff Bus) Thank you for visiting this survey page. Your participation will help us a lot, and if you leave your email address we'll send you our final report when we're finished (see our privacy statement). This study is being conducted as part of a mobility service project carried out by Kyushu University, Japan and Grameen Communications Center, Bangladesh. The survey should take less than 5 - 10 minutes. There are five sections and 36 short questions.

* Required

A. Travel for Work A periodically recurring travel between one's place of residence and place of work or study, and in doing so exceed the boundary of their residential community.

A1. What is your primary mode of transportation for commuting? *

1. Own car
2. Shared car (with friend/workmate)
3. Bus
4. Train

5. CNG
6. Rickshaw
7. Own motorcycle
8. Shared motorcycle (with friend/workmate)
9. Uber, Pathao, Cholo
10. Other ride sharing option
11. Walk
12. Other:

A2. Why do you choose your mode of transportation? Rank at least three top choices with 5 being the most important, and 1 being least important. *

Cost	1	2	3	4	5
Safety	1	2	3	4	5
Time	1	2	3	4	5
Convenience	1	2	3	4	5
Chance for socializing	1	2	3	4	5
Privacy/Independence	1	2	3	4	5
Healthy lifestyle	1	2	3	4	5
Sustainable way to commute	1	2	3	4	5
It's the only transport choice available	1	2	3	4	5

A3. On average, how long do you travel to work regularly? (in distance, one way) *

Answer:

A4. On average, how long does it take to commute to work? (in minutes, one way) *

Answer:

A5. On average, how long does it take to commute from work to home? (in minutes, one way) * Answer:

A6. Most days, what time do you arrive at work? *

Answer:

A7. Most days, what time do you leave from work? *

Answer:

A8.How much do you pay for travel to work per month?

Answer:

B. Non work travel

Trips between a person's home and other destinations which are not for the purpose of working. This could be short or long trips for leisure, shopping, hospital visit, visiting friends/family, sightseeing.

B1. Usually, how many non work trips do you make per week? (number of trips) *

Answer:

B2. How many non work trips do you make per month? (number of trips)

Answer:

B3. What is your primary mode of transportation for non work trips? *

1. Own car
2. Shared car (with friend/workmate)
3. Bus
4. Train
5. CNG
6. Rickshaw
7. Own motorcycle
8. Shared motorcycle (with friend/workmate)
9. Uber, Pathao, Cholo
10. Other ride sharing option
11. Walk
12. Other:

B4. On average, how far in distance do you travel for non work trips in a week?

Answer:

B5. On average, how far in distance do you travel for non work trips in a month?

Answer:

B6. Have you rented a car in the past 1 year?

1. Yes
2. No

B7. If yes, what are the occasions for renting a car ?

1. Weekend holiday trips
2. Attending a weeding of family event
3. Going to hometown village
4. Attending a funereal
5. Sight-seeing
6. Personal reasons
7. Other:

B8. On average, how many people would you rent a car for?

1. 2-4 persons
2. 5-8 persons
3. 9-12 persons
4. 2-4 persons
5. Other:

B10. How much do you usually spend on renting a car each time?

1. Less than 2000 BDT
2. 2000-3000 BDT
3. 3000-4000 BDT
4. 4000-5000 BDT
5. More than 5000 BDT

C. Ride sharing

A mobility service with which a person can use a smartphone app to arrange a ride in a usually privately owned vehicle.

C1. Have you ever heard about ride sharing? if yes, what kind of ride share app do you know? *

1. Uber
2. Pathao
3. O bhai
4. O bon
5. Dako
6. Shohoj
7. Not familiar with ride share app
8. Other:

C2. If you are familiar with any ride sharing service, have you ever used them?

1. Yes
2. No

C3. Are you willing to use ride share service for work travel?

1. Yes
2. No
3. Maybe

C4. Are you willing to use ride share services for non-work travel?

1. Yes
2. No
3. Maybe

C5. If you have used a ride sharing service before, please share your thoughts on the experience.

Answer:

C6. What are the potential barriers for your use of ride sharing?

1. Lack of safety
2. Unreliable
3. Unavailable for my trip
4. Lack of flexibility
5. Lack of privacy/independence
6. Cost
7. Too much tech-based
8. Waiting time
9. Other:

C7. What are some reasons why you might want to use ride sharing?

1. Cost
2. Time savings
3. Convenience
4. Adventure
5. Healthy lifestyle
6. Sustainable way to commute
7. Necessity
8. Easy to check availability
9. Don't want to use ride sharing service
10. Other:

C8. Are you familiar with the Gram Car ride share service? *

1. Yes
2. No

C9. If you are familiar with Gram Car ride share service, have you ever used the service? *

1. Yes
2. No

C10. If you have ever used Gram Car ride sharing service, please share your thoughts on the experience. Answer:

C11. Would you like to register for the next Gram Car ride share service?

1. Yes
2. No
3. Maybe
4. Other:

D. Personal background

Privacy Statement: We will never sell, share, or rent your email address or any other personal information collected on this site. This information is being collected solely for a mobility service project conducted at SocialTech lab, Kyushu University and Grameen Communications Center. Personal data will never be used in any formal publications. *We're asking for your name so that we can address you by it upon your completion of the survey. **Also, if you want to have a copy of Answer:s in this survey, please provide us with you email address at the end of this survey. It's optional.

D1. Gender

1. Female
2. Male

D2. Whats your age group?

1. 20-29

2. 30-39
3. 40-49
4. 50-59
5. 60-69
6. Other:

D3. What is your first name? (or nickname)

Answer:

D4. What is your present residential address?

Answer:

D5. From which point do you take bus/ CNG/ rickshaw to go to office?

Answer:

D6. Where do you work?

Answer:

D7. What is your occupation?

Answer:

D8. What industry is your occupation in?

1. Education
2. Management/Business
3. Healthcare
4. Administrative/Clerical
5. Information Technology
6. Sales/Marketing
7. Retail
8. Science/Engineering
9. Manufacturing
10. Government

11. Construction
12. Finance
13. Service Industry
14. Intern
15. Student
16. Other

9. If you would like a copy of the survey, please provide us your email address so we can send you a final version of our report.

Answer:

A.2 SME Employee Mid-line Survey

Route No:

Passenger ID:

We are always thankful for your participation and cooperation with us in conducting this research. The service is being provided for one month or a little more in two different routes. We would like to know if using this service made in difference in everyday function of yours. Please help us answering the question below.

Rank 1 to 3 in the scale each item and write down the relevant number of incidents.

1. Decreased
2. Haven't change
3. Increased

Table A.1: (A) Travel Safety

Issues		**Before**			**Now**		
A.1	Accidents	1	2	3	1	2	3
	Avg. number of such incidents a month						
A.2	Unwanted incidents e.g.: crowded vehicle, rough driving	1	2	3	1	2	3
	Avg. number of such incidents a month						
A.3	Harassment incidents	1	2	3	1	2	3
	Avg. number of such incidents a month						
A.4	Eve-teasing incidents	1	2	3	1	2	3
	Avg. number of such incidents a month						
A.5	Unpredicted incidents e.g.: Losing personal belongings, theft, robbery	1	2	3	1	2	3
	Avg. number of such incidents a month						

Table A.2: (B) Productivity

Issues		**Before**			**Now**		
B.1	Additional work time	1	2	3	1	2	3
	Amount of additional time a day						
B.2	Additional personal time	1	2	3	1	2	3
	Amount of additional time a day						
B.3	Waiting time on road	1	2	3	1	2	3
	Amount of additional time a day						
B.4	Mental status while entering the office	1	2	3	1	2	3
	Reasons						

Table A.3: (C) Non-monetary/ Unseen travel cost

Issues		**Before**			**Now**		
C.1	**Psychological cost**						
C.1.1	Remaining alert all through the travel	1	2	3	1	2	3
	Reasons						
C.1.2	Feeling of being safe	1	2	3	1	2	3
	Reasons						
C.1.3	Feeling of being relaxed	1	2	3	1	2	3
	Reasons						
C.2	**Energy Cost**						
C.2.1	Requires a lot of walking	1	2	3	1	2	3
C.2.2	Requires a lot of waiting on road	1	2	3	1	2	3
C.2.3	Requires a lot of adjustments	1	2	3	1	2	3

Appendix B

Rural Community Mobility Survey Questionnaire

One Community One Car - 2013

Baseline survey: GramCar Need Assessment

Table B.1: Demographic

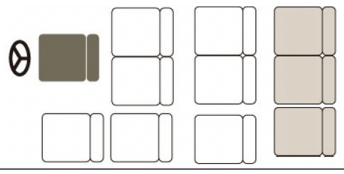
Q. #	Questions	Coding Categories	Code	Skip
101.	Please record the Sex of the respondent.	Male Female	1 2	
102.	How old are you?	Less than 20 21 - 30 31 - 40 41 - 50 50+	1 2 3 4 5	
103.	What is your profession?	Agriculture Business Private company Government service Hawker Driver Student Housewife Unemployed Other (please specify)	1 2 3 4 5 6 7 8 9 10	

Q. #	Questions		Coding Categories	Code	Skip
104.	How many members do you have in your family?		2 3 4 5 6 7 More than 7	1 2 3 4 5 6 7	
105.	How many earning members do you have in your family?		2 3 4 More than 4	1 2 3 4	
106.	What is your yearly income from different sources?		2 3 4 More than 4	1 2 3 4	
107.	What is your household expenditures in those following purpose?				
	Categories	Expenditure per month	Expenditure per year		
	1. Food				
	2. Clothing				
	3. Residence				
	4. Education				
	5. Health				

Table B.2: College Bus Service: (Respondent type: Female Student)

Q. #	Questions	Coding Categories	Code	Skip
201.	How many college going female students are there in your family?	1 2 More than 2	1 2 3	
202.	How many days in a week you go to college?	1 2 3 4 5 6	1 2 3 4 5 6	

Q. #	Questions	Coding Categories	Code	Skip
203.	Refer to Q#202, why do you stay home?	1. No regular class 2. Household work 3. Transportation problem 4. Unwillingness from parents 5. Other income generating works 6. Other	1 2 3 4 5 6	
204.	Please write college information.			
	Name of your college			
	Distance (Km)			
	Time (Min.)			
	Cost (Tk.)			
	Mode of Transportation			
205.	What kind of problems are you facing in existing transport system?	No available transport No scheduled transport Insecure transport Takes long time Costly Bad road condition Fear of eve teasing Feel uneasy to commute with male Other	1 2 3 4 5 6 7 8 9	
206.	Refer to Q#205, how to improve college going transportation system?			
207.	Where do you go before and after your college? Before: After:	 Private tution To meet friends Others ..... Private tution To meet friends Others	 1 2 3 1 2 3	
208.	Reference to Q#207, how often that happens?	Once in a week Twice in a week Thrice in a week Sometimes Often Always	1 2 3 4 5 6	

Q. #	Questions	Coding Categories	Code	Skip
209.	Do you have any experience/expose of those following?	Eve teasing Kidnapping Acid throwing Robbery Others	1 2 3 4 5	
210.	Do you want to use special vehicle to commute to college?	Yes No Others	1 2 3	
211.	How much extra do you want to pay for a high quality transport like GramCar?	Less than 5 Tk 5 - 7 Tk 7 - 10 Tk 10 - 12 Tk 12 - 15 Tk No extra payment	1 2 3 4 5 6	
212.	What seat in the car will you prefer?			

Note:
Q 211: In our project, we will arrange transportation only for female college students. In this arrangement, we will pick up female students from several points in your locality and take them in the college in scheduled time. In the same way we will also drop them after the class hour in scheduled time. If you want to get this service, you have to register with us by providing specified amount of money for the next months.

Appendix C

SSW for Rural Community Model Finance Calculation

The Services designed for Rural community are :

1. School Bus
2. Portable Health Clinic (PHC)
3. Blood Group
4. Social Goods
5. Internet
6. Emergency vehicle

Cost parameters for operating these six services are shown in Table C.1.

Share of operational costs of each services, revenues and cost cove rages are shown in the Table C.2.

Table C.1: Cost parameter details of SSW for Rural Community Model

Cost Parameters	
Hours to go and return to service point	1.5
Services Share this timing	4
Number of Day in a month	24
No. of Months	2
Car Rental Monthly	57000
Fuel Pe Day	1000
Call Center Monthly	71000
No. of Services	6
Salary	
Driver	8000
NewsPaper and Other stationaries College Bus	20
Doctor (Local)	12000
ICT Staff	10000
Support Assistant	6000
Other Cost	20000
Call Center Utiliziation	0.5
Students per return trip	22
No. of Trip	2
No. of PHC Visitors per day	30
No. of Blood Grouping per day	30
Per day Order Delivary	1
Per day Internet User	1
Per Day Emergecny Service	0.5

Table C.2: Operating cost and cost coverage

Services	**College Bus**	**PHC**	**Blood Group**	**Social Goods**	**Internet**	**Emergency**	**Idle Time**	**Total**
Car Time	3.5	0.375	0.375	0.375	0.375	2	3	10
Cost Sharing Operating Cost	0.35	0.0375	0.0375	0.0375	0.0375	0.2	0.3	1
Car Rental	39900	4275	4275	4275	4275	22800	34200	114000
Fuel	16800	1800	1800	1800	1800	9600	14400	48000
Call Center	0	71000	0	0	0	0	71000	142000
HR Salary								
Driver	5600	600	600	600	600	3200	4800	16000
Community Doctor Weightage	0	0.5	0.5	0	0	0	0	1
Community Doctor	0	12000	12000	0	0	0	0	24000
ICT Staff (weightage)	0	0.5	0.1667	0.1667	0.1666	0	0	1
ICT Staff (Local)	0	10000	3334	3334	3332	0	0	20000
Support Assistant's Weightage	0	0.5	0.1667	0.1667	0.1666	0	0	1
Support Assistant	0	6000	2000.4	2000.4	1999.2	0	0	12000
Total HR Cost	5600	28600	17934.4	5934.4	5931.2	3200	4800	72000
I. Total Operating Cost	62300	105675	24009.4	12009.4	12006	35600	124400	376000
Variable Cost								
Consumables	10	33	9	153	10	0		215
Service Receivers	2112	1440	1440	144	48	24	0	5208
II. Total Variable Cost	21120	47520	12960	22032	480	0	0	104112
III. Other Cost equally divided	3333	3333	3333	3333	3333	3333	0	20000
Grand Total	86753	156528	40303	37375	15820	38933	124400	500112
Unit Price	**20**	**80**	**30**	**175.95**	**10**	**1000**		
Income	**42240**	**115200**	**43200**	**25337**	**480**	**24000**	**124400**	**374857**
Cost Coverage	**49%**	**74%**	**107%**	**68%**	**3%**	**62%**	**100%**	**75%**