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BUS KARO

Value of transit data: Assessment of Impacts of Real-Time Information Provision to Passengers

SHAKTI SUSTAINABLE ENERGY FOUNDATION

A product of WRI Ross Center for Sustainable Cities

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1. INTRODUCTION

Technology in the form of Intelligent Transport Systems (ITS) is playing a pivotal role in transforming bus based public transport systems in Indian cities. ITS adoption has enabled bus agencies to collect huge volumes of real-time bus operations data in digital formats which can be analyzed and used to improve reliability, punctuality and efficiency of bus services. Through data analysis bus agencies can provide better bus services information (fare, timetable, routes, travel time etc.) to passengers through Passenger Information Systems (PIS) and take decisions on bus operations and management (bus schedules, routes, incidents etc.) (WRI India, 2011). Globally, transit agencies have used data for bus service planning and improvement and have successfully demonstrated the use of data to disseminate real-time information to passengers, resulting in benefits like improved reliability, time savings for passengers and ridership increase (Gillen & Levinson, 2004).

However, in India, transit agencies are mostly focused on identifying and adopting processes that use ITS data for bus operations planning and improvement. Very few agencies have used data to provide real-time information to passengers. Moreover, no bus agency has tried the 'open data' approach to share bus services information. Open data allows bus agencies to share their data free of cost in machine readable formats with external stakeholders who can then use the data to develop systems for sharing bus services information with little or no cost to the agency. The key deterrent towards this is lack of evidences in the country on range of benefits that can be achieved through provision of real-time information, estimation of the monetary value of those benefits and cost effectiveness of open data approach to provide the information.

As, more and more transit agencies are investing in ITS, it is important to bridge this knowledge gap and generate evidences on benefits of real-time information provision and the value of those benefits to various stakeholders. Such an analysis will enable informed decision making at the transit agency level on development of passenger information systems (PIS) and/or leveraging open data approach to provide information to passengers.

Accordingly, this research aims to measure the monetary value of the benefits resulting from use of ITS data to share real-time information and the value-addition of the open data in sharing information. The research, additionally, includes a qualitative assessment of the impact of open data on transport sector start-ups who are one of the main beneficiaries of open data. Located in Bengaluru, which has one of the most advanced ITS for a bus system, and has emerged as a start-up and innovation hub in the country, this study calculates the benefits that can be achieved by three stakeholders - transit agency itself, the passengers and transport sector start-ups. Towards this, our approach includes: 1) identification of the benefits of real-time information; 2) monetary quantification of these benefits in Bengaluru; 3) measurement of the investment savings gained by the bus agencies through open data and; 4) a qualitative assessment of benefits of open data for transport sector start-ups and their customers.

The report is structured as follows. First, it presents a literature review on the benefits of real-time information provision and adoption of open data approach in other geographies across the globe. The next section describes the methodology detailing the case city, data collection, data analysis and results. This is followed by description of the limitations of the analysis and the conclusion.

2. LITERATURE REVIEW

The research on understanding the benefits of using ITS data to provide real-time bus services information and measuring the value of those benefits is mostly located in the cities of United State of America where transit agencies and other stakeholders have developed systems such as display boards and mobile applications to share information with passengers. Researchers have conducted user behavior experiments in cities like Tampa (Brakewood, Barbeau, & Watkins, 2014) and Seattle (Watkins, Ferris, Borning, Rutherford, & Layton, 2011) and empirical evaluations in cities like New York (Brakewood, Macfarlane, & Watkins, 2015) and Chicago (Tang & Thakuriah, 2012) to measure the impacts of real-time information availability. These studies suggest that real-time information reduces the wait-time of passengers at bus stops and increase the transit ridership, amongst other secondary benefits. The impact is influenced by the ability of the users to adapt to the unreliability of the system because of real-time information. Brakewood et.al (2014) noted similar findings from previous behavioral studies conducted using stated preference and/or simulation methods. They summarized the benefits of real-time information availability as: 1) decreased wait-times, 2) increased satisfaction with the transit service and 3) increased ridership.

These benefits-wait time savings and ridership increase, can respectively translate into monetary gains as value of wait-time savings for passengers and increased fare-box revenue for bus agencies. Moreover, the monetary gains by the bus agencies can be multiplied by providing bus services information in a cost-effective manner through 'open data' approach (Brakewood, Barbeau, & Watkins, 2014). Open data initiatives allow bus agencies to share their data free of cost in machine readable formats with external stakeholders (Schweiger, 2015). Software developers and other start-ups can then use this data to develop systems for sharing bus services information with little to no-cost to the bus agency. It is important to note that open data, in turn, can foster growth of existing and new start-ups and businesses that offer innovative mobility solutions. Open data helps foster economic growth, new forms of innovation, create employment and generate revenue (Verhulst & Young, 2017).

The benefits arising from real-time bus information and use of open data approach are discussed in detail in the following review, divided into:

1. Wait-time savings for passengers;
2. Increase in transit ridership;
3. Investment savings by the transit agency through open data approach and;
4. Impact of open data on transport sector start-ups

a) Wait-time savings for passengers

Wait-time at the bus stop is the most negatively weighted component of the trip made using a bus due to the uncertainty associated with the availability of the bus and the estimated time of arrival of the bus at the bus stop. Bus users' value knowing their wait-time or whether they have missed the last bus (Ferris, Watkins, & Borning, 2010).

Access to real-time information helps passengers to schedule their departure from their origin so that wait-time at bus stops is minimized. In Seattle, researchers measured that bus passengers with access to real-time information had actual wait-time that were almost 2 minutes less than those of users with access to static information (Watkins, Ferris, Borning, Rutherford, & Layton, 2011). Similar results were also observed in Tampa where researchers conducted a before-after control group experiment. They analyzed that wait-time for experimental group with access to real-time information is nearly 2 minutes less than the wait-time for the control group with no access to information (Brakewood, Barbeau, & Watkins, 2014).

The wait-time savings experienced by passengers who use real-time information versus passengers who use no information and/or use static information can translate into monetary benefits measured as value of wait-time savings. Public transport users in London (2012) are estimated to save anything between £15 million to £58 million per annum due to availability of real-time information on the city public transport services. The monetary benefit calculations are dependent on the level of information use and the ability of passengers to make decisions based on information (Hogge, 2016). It is valuable to note that public transport services information in London is provided to passengers by third party businesses/start-ups who use Transport for London (TfL)'s open data to develop mobile applications which are available for free download.

b) Increase in transit ridership

Real-time bus services information empowers the passengers to plan and decide their trips as per their needs and convenience. They feel more in control of their trip which enhances their journey experience and positively impacts their perception of reliability of the bus system. Increased reliability of the system leads to increase in the frequency of bus trips made by existing users and attracts new users to buses. It has been demonstrated that real-time information availability can result in mode shift to public transportation (Multisystems, 2003). It is for the same reasons that OneBusAway - the transit traveler information system in King County, aims to provide better transit traveler information to passengers (Watkins, Ferris, Borning, Rutherford, & Layton, 2011). Researchers in Tampa (Brakewood, Barbeau, & Watkins, 2014) and New York (Brakewood, Macfarlane, & Watkins, 2015) measured an increase of 2 percent in transit ridership due to real-time information availability. Similarly, in Boston, an increase of 1.4 percent in ridership was witnessed (Zanghi, 2017).

The ridership increase boosted by the availability of real-time information will result into increase in fare-box revenue collection for the bus agency. Brakewood et.al (2015), using simple approximation methods, estimated that the total additional weekday fare-box revenue per month in New York City grew from zero USD (prior to availability of real time information) to approximately USD 400,000 (when real-time information was available) over a study period of three years.

c) Investment savings by the transit agency through open data approach

The telematics-based PIS such as mobile applications, website and digital display boards adopted by transit agencies to provide real-time information to passengers are investment heavy. Digital display boards are expensive for initial purchase and maintenance, thereby limiting the number of stops at which real-time information can be made available (Schweiger, 2003) and dedicated financial and technical resources are required to periodically update the websites and mobile applications. Financially constrained bus agencies instead should adopt cost effective solutions which require lowest level of skill to ensure high quality information delivered over the web (Jain, Parida, & Jain, 2014).

One cost-effective way of achieving this is through an open data approach. Open data allows bus agencies to share data with external stakeholders in easy-to-read formats, free of cost. Software developers and other start-ups can use the open transit data to deliver bus services information to citizens in a range of innovative ways without the transit agency making any additional investments (The World Bank , 2014).

Software developers in cities like London (Trasport for London, n.d.), Boston, New York (Metropolitan Transport Authority , n.d.) and Singapore (Land Transport Data Mall, n.d.) have successfully used open data to develop tools that provide real-time information on variety of interfaces with little to no cost to the bus agencies. Transport for London (TfL)'s open data initiative led to the development of 362 mobile applications (2014) - all aimed at providing public transport information to TfL's customers. This enabled them to avoid approximately £15 million-42 million in in-house development of similar applications. At the same time, the cost of putting out the data in a readable and reliable format costed only £ 1 million to TfL (Hogge, 2016). Similarly, private businesses in Boston used the public transport vehicle location dataset released by the authorities to develop free of cost mobile applications, desktop widgets, LED signs, SMS based service and a free automated phone-line to provide information to passengers. The agency was able to be the basis for multiple customer service without any additional expense (The World Bank , 2014). The outreach of systems developed by private businesses was more and they were cheaper to deploy when compared with investments made by the transit agency. These systems also helped the transit agencies to meet the increased expectations of individual travelers who want personalized transit information on their mobile devices. Systems developed by the private sector are superior in terms of user-friendliness and information content when compared with the websites of public transport agencies (Jain, Parida, & Jain, 2014).

d) Impact of open data on transport sector start-ups

Open data directly benefits the entrepreneurs/start-up community. Research conducted by The World Bank (2014) highlights that the key policy driver for increased adoption of open data policies around the world have been its ability to drive economic growth and business innovation. Open data allows the governments to use their existing datasets as a platform on which business can develop services and applications which deliver additional benefits to the public (The World Bank , 2014).

Transit data can be used to develop mobile applications that provide users real-time information on bus services integrated with other modes and develop services that supplement the existing bus system. The execution of these ideas by the start-up community has the potential to establish new businesses, foster growth of existing businesses, create jobs, influence economic growth and attract angel-investments. The open data initiative by TfL for London helped create 362 mobile applications which provided job opportunities. It also helped create successful start-ups like MX Data and City Mapper which have grown into larger tech companies with services in other global cities. The Metropolitan Transport Authority, New York released the real-time bus tracking information to software developers in parallel to the launch of MTA managed interfaces. This resulted in availability of 65 iphone apps, 47 android apps, 7 blackberry apps and 7 windows apps (Metropolitan Transport Authority , n.d.) created by independent third-party developers.

3. RESEARCH QUESTIONS

Based on the review, this research aims to generate evidences and measure the monetary value of the benefits resulting from use of ITS data to provide real-time bus services information to passengers in Indian cities. It also assesses the additional monetary benefits that can be generated through open data approach and the impact of open data on transport sector start-ups. The study is restricted to measure the value of ITS data by estimating:

1. What monetary benefits accrue to passengers due to reduction in wait-time measured as value of wait-time savings?
2. What monetary benefits accrue to the transit agency due to increase in ridership measured as the increase in fare-box revenue collection?
3. What monetary benefits accrue to the transit agency due to adoption of open data approach measured as the avoided costs of developing a PIS?
4. What is the impact of open data on transport sector start-ups and their customers?

4. METHODOLOGY

This section describes the methodology adopted for this research. It includes details on the case city, data collection and data analysis.

a) Case City

Bengaluru was selected as the location for the study for two reasons. First, Bengaluru Metropolitan Transport Corporation (BMTC), the city bus agency in Bengaluru, has one of the most advanced ITS in the country with a functional PIS and is working to adopt an open data policy. Second, Bengaluru has emerged as a start-up and innovation hub in India and the possibilities of open transit data being used to develop innovative transport solutions is maximum here.

BMTC operates 6627 buses on 2300 routes per day enabling completion of 4.9 million passenger trips (Bengaluru Metropolitan Transport Coproration, n.d.) of the total 10 million passenger trips (Bangalore Development Authority, 2017) in the city. To manage this scale of operations, BMTC modernized its system by adopting ITS in 2016. The ITS comprises of Electronic Ticketing Machines (ETMs) and Vehicle Tracking Units (VTUs) installed on buses and a Control Centre which allows monitoring of operations from a central location. The two devices capture the following information:

- ETM: route numbers, schedule numbers, trip number, origin and destination of the trip, fare collected, date and time
- VTU: real time location of the bus on the route

The ITS also has an attached PIS which comprises of 35 digital display boards installed at 11 major bus stations in the city (not all are functional) and a mobile application. The digital display boards provide real-time information on buses arriving and departing from the bus station. The mobile application, called the BMTC app, provides trip planning assistance and helps locate buses on various routes with estimated time of arrival (ETA) at the bus stop. In addition, majority of the bus stops in the city have printed display boards which provide static information on bus routes passing through the bus stop.

Figure 1: Left to right-Digital Display boards at bus stations, BMTC's Mobile application

b) Data Collection and Analysis

To address the research questions of this study, primary surveys and structured interviews with three stakeholders- passengers, transit agency and start-ups were conducted in Bengaluru. The surveys are summarized in table 1 with detailed description in the following sections:

Table 1: Summary of data collection surveys

S.No.	Survey Type	Measured Indicator	Participants	Objective
1	Primary surveys using a combination of stated and revealed preference questionnaires*	Wait time savings by passengers	Bus Users	To capture the existing wait-time of bus-users who access bus services information versus bus-users who do not access any kind of information and use traditional forms of information.
2		Increase in transit ridership	Bus Users and Non-bus users	To capture the increase in bus trip frequency by existing bus users and non-bus users due to information availability.
3	Structured interviews	Investments in BMTC's ITS enabled PIS	BMTC	To understand BMTC's ITS and the investments made in developing and implementing the PIS.
4	Structured interviews**	Growth of start-ups	Transport sector start-ups	To understand and capture the impacts of open bus data on start-ups.

* *This approach was selected because of the need to capture behavioral changes resulting from availability of real-time information* (Tang & Thakuriah, 2010)

*** This approach was selected because at the time of conducting this study no bus agency in India had opened its data. As such, it was difficult to conduct a before and after comparison to quantify the growth. It is due to the same reasons that the results of these interviews are presented using qualitative analysis methods.*

Primary survey for measuring wait-time savings and increase in transit ridership

To collect data on wait-time savings and ridership for the 10 million passenger trips made in Bengaluru per day through primary surveys, we selected a sample of 1,067[1]. Based on the number of trips made using buses (4.9 million) and other modes (5.1 million), the sample was stratified to capture 523 bus users and 544 non-bus users. The participants categorized as 'bus users' comprise of people who use bus for their commute daily and/or few times a week. The participants categorized as 'non-bus users' comprise of people who do not use buses at all. This sampling strategy captures heterogeneity in socio-economic and travel characteristics of bus users and non-bus users. During data collection exercise, data was collected for 596 bus users and 542 non-bus users and analysis is based on these samples. The socio-economic details of participants are provided in table 4.

This primary survey was administered in three areas in Bengaluru - Peenya Industrial Area, Electronic City and Whitefield. These areas were selected because they are the three major economic and employment zones in the city (Bangalore Development Authority, 2017) and generate maximum number of work trips. Spatially, these areas are situated along the major highways passing through the city - the Tumkur Road, the Hosur Road and the Old Airport Road as indicated in figure 2. To capture bus users, the surveys were conducted at select bus stops on the highways where maximum boarding-alighting on buses takes place. To capture non-bus users, the surveys were conducted at randomly selected trip generation points like tech parks, markets and residential areas. The surveyors were instructed to capture only those respondents who board or alight a vehicle at these points.

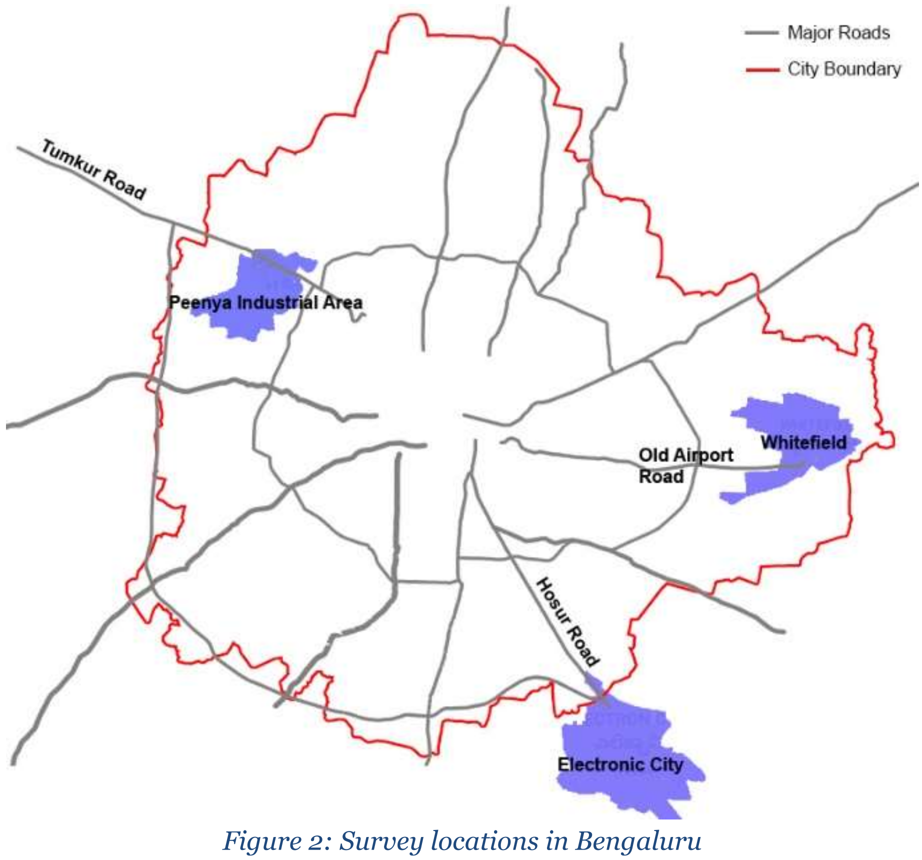

Figure 2: Survey locations in Bengaluru

[1] Confidence level: 95 percent; Confidence interval: 3

Wait-time savings: Data for measuring the wait-time savings was collected from participants categorized as bus users. It is these participants who will experience variations in their wait-times as compared to participants categorized as 'non-bus users'. The 596 bus users were asked to state the medium they currently use for accessing information on bus services from the following options - printed display boards at bus stops (static information), digital display boards at bus stops (real-time information), BMTC app/website (real-time information) and other mobile apps like google transit (static information). Participants who did not access any information could state the same.

As mentioned in table 2: 60.90 percent participants used real-time bus services information to make their trips while remaining 39.10 percent either accessed static bus information available through printed displays or did not access any information. Subsequently, all 596 participants reported their current wait times at the bus stop which was explained to them as the time interval from the moment of arriving at the bus stop till boarding the bus.

Table 2: Medium of information services

Medium	Number	Percentage
BMTC app/website	180	30.20
Digital display boards at bus stops	183	30.70
Others- google transit etc.	5	0.84
Printed display boards at bus stops	92	15.44
Do not access information	136	22.82
Total	**596**	**100**

Using the 'independent difference of means t-test' (Watkins, Ferris, Borning, Rutherford, & Layton, 2011), the reduction in wait-time for bus users who use information in comparison to bus users who do not use information and/or use static information was calculated. The equation, below, measures the reduction in wait time by taking the difference between the mean wait time for users with real-time information and users with no and/or static information.

$$\tau_{savings} = \mu_{real-time\ Information} - \mu_{no\ information+static\ information}$$

Where

$\tau_{savings} = wait\ time\ savings\ per\ trip$

$\mu_{Real-time\ information} = mean\ wait\ time\ for\ users\ with\ access\ to\ real-time\ information$

$\mu_{no\ information+static\ information}$
$= mean\ wait\ time\ for\ users\ with\ access\ to\ static\ information\ and\ no\ access\ to\ information$

Considering 60.91 percent (as obtained from the survey) bus users at the city level use bus services information to make their trips the total wait-time saved in the city is calculated. Further, the monetary value of the wait-time saved is obtained by multiplying it with the monetary value of one hour for Bengaluru.

$$VoT_{wait-time\ savings} = \left[\frac{\tau_{savings}}{60}\right] * (A * T) * VoT$$

<u>*Where*</u>

$VoT_{wait-time\ saving}$ = *Monetary value of wait time savings*

$\tau_{Savings}$ = *wait time savings per trip*

A = percentage of information usage in the city

T = total trips using BMTC buses in Bangalore

VoT = monetary value of one hour in Bangalore

Increase in ridership: The increase in bus ridership analysis assumes that real-time information attracts choice trips i.e. passengers who use buses infrequently (do not make the trip on all days) and the passengers who do not use buses at all (use alternate modes of transport). The shift is likely to be influenced by the availability of real-time information on bus arrival at the moment when user is deciding to make the trip or choosing the mode of the trip. Checking real-time bus information before the trip may reveal that a bus is few minutes away and consequently the user may choose to make the trip using bus versus an alternate mode (Brakewood, Macfarlane, & Watkins, 2015). Additionally, there is a likelihood that people who cancel their trips when they miss the bus may make the trip if they know that the next bus will arrive in next few minutes.

These choice trips, which have the potential to shift to buses, were captured through the primary survey conducted (using separate questionnaires) for 596 participants categorized as bus users and 542 participants categorized as non-bus users. All participants were asked to report their current trip frequency of using the bus per week. As shown in table 3: 85.06 percent respondents from the bus users' category can be classified as daily users making 10-14 trips per week. The remaining participants can be classified as infrequent users making 1-9 trips per week. These two types of users were respectively asked their mode choice when they miss the bus and during other days of the week. It was observed that 471 daily users are captive users who wait for the next bus for completing their trip and were thus left out from further analysis. The remaining 36 daily users either forgo the trip or use another mode. These 36 participants along with the 89 participants classified as infrequent users (total 125 participants) were asked to state if they accessed bus services information. It was found that among these 92 participants already use information to make their trips. Therefore, they were left out from further analysis as information availability may have already impacted their behavior. The remaining 33 participants were interviewed about their preference of using bus services if reliable information was made available. 4.02 percent (24 participants) of the total participants reported their willingness to make more trips using the bus.

Table 3: Existing trip frequency

Trip frequency	Bus Users	Percentage
< 4 trips	58	9.74
4-9 trips	31	5.20
10-14 trips	507	85.06
Total	**596**	**100**

Participants categorized as 'non-bus users' were surveyed to recognize their reasons for not using the bus services. It was observed that only 2.3 percent of the total participants do not use the bus due to lack of information on bus services[2]. These participants were asked to state their willingness to use the bus if information is available and the number of trips per-week they will make using the bus system. Only 2 percent (11 participants) of the total participants reported their willingness to shift to BMTC buses.

Considering that 4.02 percent (as obtained from the survey) of the existing bus-users will make additional trips using BMTC buses and 2 percent (as obtained from the survey) of the non-bus users will shift to BMTC buses, the total increase in number of trips due to information availability is calculated for Bengaluru.

$$Percentage\ increase\ in\ trips\ (Z) = \frac{(X * \mu_{increase\ in\ trips})}{(Y * \mu_{existing\ trips})} * 100$$

<u>*Where*</u>

X = No of survey participants shifting to bus

Y = Total survey participants

$\mu_{increase\ in\ trips} = Average\ increase\ in\ number\ of\ trips\ due\ to\ information$

$\mu_{existing\ trips} = Average\ existing\ trips$

The increase in fare box revenue is calculated by multiplying the increase in ridership by the average fare per trip for the city.

$$I_{fare-box} = [(Z_{bus\ users} * T_{bus\ users}) + (Z_{non-bus\ users} * T_{non-bus\ users})] * \mu_{fare}$$

<u>Where</u>

$I_{fare-box} = increase\ in\ fare - box\ revenue$

$Z_{bus\ users} = percentage\ increase\ in\ trips\ by\ bus\ users$

$T_{bus\ users} = Total\ trips\ by\ bus\ users\ in\ Bengaluru$

$Z_{non-bus\ users} = percentage\ increase\ in\ trips\ by\ non - bus\ users$

$T_{non-bus\ users} = total\ trips\ by\ non - bus\ users\ in\ Bengaluru$

$\mu_{fare} = average\ bus\ fare\ in\ Bengaluru$

Structured interview with BMTC

Structured interviews were conducted with senior officials from BMTC to understand their ITS and the investments made by the transit agency in its implementation especially the PIS components. The key questions asked to the authority included the investment directed towards development of the PIS.

[2] The remaining participants cited the following reasons for not using the bus: convenience of private vehicles, lack of direct bus services between their origin and destination/difficult interchange, poor access to /from bus stops and lack of frequent bus services.

Structured interviews with start-ups

Structured interviews were conducted with the founders and heads of 11 start-ups including trip planning apps, bus aggregators and public bicycle sharing systems who have existing services in Bangalore or are planning to begin services. Only those start-ups were approached for the survey who would directly benefit from open transit data. The 11 start-ups were then selected based on their interest to participate in the study. The participants were interviewed about the dependence of the service provided by them on BMTC's data and the manner in which data availability can impact their user growth. The key questions asked to the start-ups interviewed for this study included information on the service/product and the business plan, the degree of dependence of success of business plan on BMTC's data, type of data required from the bus agency for execution of the business plan, availability of the bus agency data, alternate strategy to procure bus agency's data in its absence, impact of data availability on user growth and link between data availability and investor funding.

However, in the absence of any open transport data initiative in the country, it was difficult to quantify the growth of the start-ups which can be attributed bus agency's open data. As such, the impact of open data on start-ups growth is not included in the final calculations measuring the value of transit data. Instead, a qualitative analysis of the surveys is provided below.

5. RESULTS

This section includes details on the results of the analysis i.e. the monetary value of the wait-time savings experience by the passengers, expected increase in fare-box revenue for the transit agency and estimation of the investment savings by the bus agency due to adoption of open data approach for information sharing instead of developing the PIS. The section also summarizes the findings from interviews with the start-ups.

a) Demographic Profile of users

Table 4: Socio-economic characteristics of survey participants

Gender						
Gender	Bus users		Non-Bus users		Total	
	Number	Percentage	Number	Percentage	Number	Percentage
Male	492	82.6	442	81.5	934	82.1
Female	104	17.4	100	18.5	204	17.9
Total	596	100.0	542	100.0	1138	100.0

Age Group						
Age Group	Bus users		Non-bus users		Total	
	Number	Percentage	Number	Percentage	Number	Percentage
Below 20	40	6.7	41	7.6	81	7.1
20-30	387	64.9	280	51.7	667	58.6
30-40	112	18.8	168	31.0	280	24.6
40-50	10	1.7	23	4.2	33	2.9
Above 50	5	0.8	3	0.6	8	0.7
Prefer not to say	42	7.0	27	5.0	69	6.1
Total	596	100.0	542	100.0	1138	100.0

Sector of Employment/Work						
	Bus users		Non-bus users		Total	
	Number	Percentage	Number	Percentage	Number	Percentage
Agriculture	6	1.0	4	0.7	10	0.9
Business	9	1.5	12	2.2	21	1.8
Construction/Real Estate	21	3.5	26	4.8	47	4.1
Education	134	22.5	130	24.0	264	23.2
Information Technology	217	36.4	148	27.3	365	32.1
Manufacturing	91	15.3	127	23.4	218	19.2
Non-Profit	50	8.4	23	4.2	73	6.4
Others	20	3.4	12	2.2	32	2.8
Public Sector	5	0.8	17	3.1	22	1.9
Retail	34	5.7	40	7.4	74	6.5
Unemployed	9	1.5	3	0.6	12	1.1
Total	596	100.0	542	100.0	1138	100.0

Trip Purpose						
	Bus users		Non-bus users		Total	
	Number	Percentage	Number	Percentage	Number	Percentage
Education trips	130	21.8	112	20.7	242	21.3
Recreational trips	13	2.2	15	2.8	28	2.5
Social trips	36	6.0	50	9.2	86	7.6
Work trips	417	70.0	365	67.3	782	68.7
Total	596	100.0	542	100.0	1138	100.0

Smart Phone Ownership and Internet Use								
Internet Use	Yes				No			
Smart Phone	Bus Users		Non-bus Users		Bus Users		Non-bus Users	
	Number	%age	Number	%age	Number	%age	Number	%age
Yes	489	82.0	476	87.8	57	9.6	41	7.6
No	3	0.5	1	0.2	47	7.9	24	4.4

b) Wait-time savings and value of wait-time savings

The stated wait-time of participants lie between 0 to 45 minutes. The mean wait time for bus users who make their trips using real-time information is reported to be 13.00 minutes whereas the mean wait time for bus users who make their trips either by using static information or without using any information is 15.22 minutes. **The difference between the two figures indicate that users who use real-time information save 2.22 minutes per trip versus users who use static and/or do not use information which is statistically significant (t=2.88, p value = 0.00).**

At city level, for 4.9 million passengers' trips completed using BMTC buses, the total wait time saved is estimated to be **6,623,412.12 minutes or 110,390.20 hours per day**. Considering the monetary value of time in Bengaluru as INR 34.68 per hour (Embarq India, 2014), **the value of wait time savings for citizens is estimated to be INR 3,828,332.21 per day.**

c) Increase in ridership and impact on fare-box revenue

The average increase in trips for bus users who make infrequent trips is calculated as 2.41 trips per person per week. Similarly, the average increase in trips for non-bus users is calculated as 6.36 trips per person per week.

Considering that the existing average trips in Bengaluru lie between 8.9 and 12.7 trips per person per week, the rate of increase of trips is estimated to lie between **0.76 and 1.09 percent for bus users** and **0.92 and 1.45 percent for non-bus users**. At the city level, the increase in number of trips made using BMTC buses will vary between 37,443 trips to 53,430 per day for bus users and 47,138 to 73,966 per day for non-bus users. The total increase in trips will vary from 84,581 to 127,396 trips per day. Assuming the average fare for Bangalore as INR 17 per trip (BMTC ITS data), the average increase in fare-box collection is estimated to be INR 754,809.84 per day from increase in number of trips by existing bus users and 785,618.41 due to mode shift (non-bus users). **The total average increase in fare box revenue is estimated to be INR 1,540,428.25 per day. This is approximately 3.08 percent of the daily traffic revenue earned by BMTC.**

d) Investment savings by BMTC through open data approach

BMTC launched the ITS in May 2016 (Bengaluru Metropolitan Transport Corporation, n.d.) with an investment of INR 69.86 crores over a period of five years from 2016- 2021. A significant portion of this investment was directed towards the development of the PIS which comprises of 35 digital display boards at 11 major bus stations and the BMTC app. BMTC has made one-time investment of INR 6,000,000 to develop the mobile application.

While PIS boards are necessary for the advantage of passengers who do not have access to mobile devices, BMTC could have avoided the costs of developing the mobile application by opening its data and allowing third party developers to develop mobile applications. The costs avoided is a direct monetary gain to the agency arising from sharing the ITS data. Additionally, as observed form the experiences of other international cities, this cost savings is a conservative estimate. Use of data by third party developers can lead to development of numerous applications which share information in numerous ways that suit the needs of various individuals. Developing the same number of applications to cater to needs of all individuals will require additional investments from the bus agency.

e) Impact of open data on transport sector start-ups

BMTC's data is extremely important for transport sector start-ups because BMTC buses help complete 49 percent of the total trips made in the city making it the owner of almost half the data on city travel characteristics. Trip Planning apps, which help passengers plan their trips from origin to destination by providing information on the available transport modes and required interchanges believe that buses should appear as a travel option alongside other transport modes. With lack of information on buses, it is likely the transit agency will lose ridership. The situation is exaggerated by the fast-moving ecosystem where passengers want transit information on their mobile phones in styles that best suit their needs. For example, currently, the BMTC's mobile application provides information only on bus services. It is restrictive in nature as it does not allow for integration of information on other modes – metro, cab hailing services, public bicycle sharing systems etc. Development of applications that provide bus information by private companies/start-ups ensures that transit information reaches wider audience with little to no cost to the bus agency. Additionally, BMTC's data is important for realizing the 'Mobility as a Service (MaaS) concept, which enables access to transport through range of different public and private services without the need for vehicle ownership.

Start-ups that are working to develop public bicycle sharing systems in Bengaluru also expressed the need to have access to BMTC's data. Availability of data can help them to better integrate their services with BMTC's services and act as a last-mile connectivity option for passengers. They primarily require data for planning their services and cycle redistribution system, keeping a constant fleet strength of cycles at bus stops. Transit data is also highly sought by 'Bus Aggregators' who provide transport services by aggregating privately owned buses which seat approximately 18-20 passengers. The services differ from those offered by public bus agencies by enabling passengers to track bus timings and arrival and assuring seating for the duration of their journey. Availability of transit data can help these operators to better integrate their services with those of the public system and provide better geographical coverage through public transport modes.

All participants confirmed that open transit data can help them grow their businesses. Data can be used to improve user experience which will help attract new users and retain existing users. However, the participants were unable to quantity the user-growth that can be attributed to open data. Nonetheless, few start-ups are using secondary transit data available in public domain. It is, however, a time-consuming process as data requires cleaning and digitization

6. LIMITATIONS

There are a few limitations to the wait-time savings and ridership increase analysis, as mentioned below:

1. The data collected for the study is self-reported data and not a direct measurement of the participants' behavior. The accuracy of data used for the analysis depends on the ability participants to correctly estimate their trips attributes – wait-time and ridership.
2. It is likely that the participants have stated their wait-time as per their perception in comparison to their actual wait–times at the bus stops. Previous studies have indicated

that self-reported wait times may not align with the actual wait times due to perception of time (Watkins, Ferris, Borning, Rutherford, & Layton, 2011). The actual wait-times may be less or more than the stated wait-times in the survey.

3. Similarly, the ridership increase calculated using the survey data may vary on ground. It is possible that passengers who stated their intent to shift and/or to make more trips using buses may or may not make the transfer.
4. The average daily fare per trip for the city has been calculated using the tickets sold. It excludes pass holders who make daily, monthly or annual payments to the bus agency.
5. The surveys were conducted in areas served by larger number of routes with high bus frequency. There may be slight variations in areas which are inadequately served by BMTC buses.
6. The surveys were conducted by a third party hired for data collection. Though necessary checks were conducted at survey locations to control the quality of data, there may be instances where incorrect data has been captured.

7. CONCLUSION

This research was conducted to generate evidences on the benefits including financial gains of providing real-time information to passengers. It also estimated the benefits that can accrue to a transit agency due to adoption of open data approach for sharing information. Such an analysis will help decision makers to prioritize their interventions while adopting ITS measures, implementing systems for sharing information with passengers and open data policies. Taking the case example of Bengaluru, the research approach comprised of three main steps. First, through literature review, it identified the key benefits that can be achieved by provision of real time information especially through an open data approach. Second, we estimated the monetary value of these benefits to two key stakeholders i.e. the passengers and the bus agency. Lastly, it evaluated the investments that the city bus agency could have avoided by adopting open data instead of developing the information systems by itself. As a secondary output, the impact of open bus agency data on the transport sector start-ups was also measured.

ITS data when used to provide information to passengers benefits two key stakeholders – the passengers and the bus agency itself. While the passengers experience less wait-time at the bus stops, the bus agency experiences increased ridership due to improved reliability of the systems. In Bengaluru, it was observed that passengers with access to real-time information have wait-time which is 2.22 minutes less as compared to wait-time of passengers who do not access any information and/or use static information. **The wait-time savings when measured as value of time savings amount to INR 3,828,332.21 per day at the city level for passengers.** The wait-time reduction coupled with information of bus availability and estimated bus arrival times improves the reliability of the bus system; thus, attracting choice users to the bus systems. As a result, the bus agency witnesses an increase in ridership. In Bengaluru the expected increase in bus ridership due to real-time information availability is estimated to be between 84,581 to 127,396 trips per day. **These trips when translated as fare-box revenue can result in additional earnings of INR 1,540,428.25 per day for BMTC.**

Altogether, the total monetary value of the data that can be used to provide real-time information is calculated as the sum of value of wait-time savings and increase in fare-box revenue for the bus agency. In addition, more monetary benefits can be created by adopting the open data approach for information sharing. The bus agency can avoid the investments directed towards development of telematics based PIS. The total value of ITS data can be calculated as:

$$Value\ of\ ITS\ data = \sum (VoT_{wait-time\ savings} + I_{fare-box} + Investments\ avoided)$$

At the city level, Bengaluru can generate monetary benefits of approximately INR 5,368,760.46 per day through real-time information sharing and BMTC can avoid the costs (INR 6,000,000) directed towards development of the BMTC app. However, this is a conservative estimate as it does not include the monetary value of additional economic and social benefits from open data. This also does not include the economic benefits that are generated in terms of growth of existing and emergence of new start-ups due to open data.

In summary, there is immense value in the data collected using ITS if utilized appropriately. Transit agencies who are investing in implementing ITS for operations should also focus on providing real-time information to passengers to maximize the returns on their investments. Approaches like open data will not only help the transit agency and the start-ups but will also help to strengthen the overall transport system in the cities and foster innovation.

8. REFERENCES

Bangalore Development Authority. (2017). *Revised Master Plan for Bengaluru - 2031 (Draft).*

Bengaluru Metropolitan Transport Coproration. (n.d.). Retrieved from http://www.mybmtc.com/en/bmtc_glance

Bengaluru Metropolitan Transport Corporation;. (n.d.). *Launching of BMTC's Intelligent Transport System.* Retrieved April 30, 2018, from https://www.mybmtc.com/en/press-release/launching-bmtc%E2%80%99s-intelligent-transport-systemits

Brakewood, C., Barbeau, S., & Watkins, K. (2014). An experiment evaluating the impacts of real-time transit information on bus riders in Tampa, Florida. *Elsevier.*

Brakewood, C., Barbeau, S., & Watkins, K. (2014). An experiment evaluating the impacts of real-time transit information on bus riders in Tampa, Florida. *Transportation Research Part A : Policy and Practice.*

Brakewood, C., Macfarlane, G. S., & Watkins, K. (2015). The impact of real-time information on bus ridership in New York City. *Elsevier.*

Brakewood, C., Macfarlane, G. S., & Watkins, K. (2015). The Impact of real-time information on bus ridership in New York City . *Transportation Research Part C: Emerging Technologies .*

Deloitte. (2013). *Market Assessment of Public Sector Information.* Department for Business innovation and Skills;. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/198905/bis-13-743-market-assessment-of-public-sector-information.pdf

Embarq India. (2014). *Bangalore Bus Rapid Transit System (BRTS) Detailed Project Report .*

Ferris, B., Watkins, K., & Borning, A. (2010). OneBusAway: Results from providing real-time Arrival Information for Public Transit . *CHI* , (pp. 1807-1816). Atlanta.

Gillen , D., & Levinson, D. (2004). *Assessing the Benefits and Costs of ITS- Making Business Case for ITS Investments*. New York: Kluwer Academic Publishers.
Gillen , D., & Levinson, D. (2004). *Assessing the Benfits and Costs of ITS Making the Business Case for ITS Investments* . Boston: Kluwer Academic Publishers .
GovLab, Omdiyar Network. (2016). *Open data's impact - Transport for London, Get Set, Go!* New York, USA: GovLab. Retrieved from http://odimpact.org/files/case-studies-transport-for-london.pdf
Hogge, B. (2016). *Open Data's Impact Transport for London Get Set, Go! GovLab, Omidyar Network* .
IBM. (2013, May 17). *Big Data Helps City of Dublin Improve its Public Bus Transportation Network and Reduce Congestion*. Retrieved February 22, 2018, from https://www-03.ibm.com/press/us/en/pressrelease/41068.wss
Jain, G. V., Parida, M., & Jain, S. S. (2014). Critical Appraisal of Web-Based Passenger Information Systems . *Journal of Public Transportation, Vol. 17, No. 3*.
Land Transport Data Mall. (n.d.). Retrieved June 20, 2018, from https://www.mytransport.sg/content/mytransport/home/dataMall/app-zone.html
Metropolitan Transport Authority . (n.d.). *Metropolitan Transport Authority*. Retrieved May 30, 2018, from http://web.mta.info/apps/
Multisystems. (2003). Strategies for Improved Traveler Information, Report 92. *Transit Cooperative Research Program*.
Schweiger, C. L. (2003). Real-Time Bus Arrival Information Systems. *Transit Cooperative Research Program, Synthesis 48*.
Schweiger, C. L. (2015). Open Data: Challenges and Opportunities for Transit Agencies . *Transit Cooperative Reserach Program Synthesis 115*.
Tang, L., & Thakuriah, P. (2010). Will the Psychological Effects of Real-time Transit Information Systems Lead to Ridership Gain? *Proceedings of the 2010 Annual Meeting of the Transportation Research Board, Washington, D.C.*
Tang, L., & Thakuriah, P. (2012). Ridership effects of real-time bus information system: A case study in City of Chicago. *Transportation Research Part C : Emerging Technologies* .
The World Bank . (2014). *Opportunities and Strategies for Mainstreaming Open Data in Transport Projects in St. Petersburg* .
The World Bank. (2014). *Opportunities and strategies for mainstreaming open data in transport projects in St. Petersburg*.
Trasport for London. (n.d.). Retrieved June 20, 2018, from https://data.london.gov.uk/case-studies/transport-apps/
Verhulst, S. G., & Young, A. (2017). *Open Data in Developing Economies-Towards building an evidence on what works and how*. The Gov Lab.
Watkins, K. E., Ferris, B., Borning, A., Rutherford, G. S., & Layton, D. (2011). *Where Is My Bus? Impact of mobile real-time information on the perceived and actual wait time of transit riders*.
Watkins, K. E., Ferris, B., Borning, A., Rutherford, G. S., & Layton, D. (2011). Where is My Bus? Impact of mobile real-time information on the perceived and actual wait time os transit riders. *Transport Research Part A: Policy and Practice*.
WRI India. (2011). *Bus Karo 2.0 Case Studies from India*. Mumbai : WRI India.
WRI India. (2011). *Bus Karo 2.0 Case Studies from India*.
Zanghi, B. (2017, May 17). How Smart Cities Can Increase Public Transit Ridership (Industry Perspective). *Future Structure*. Retrieved from

http://www.govtech.com/fs/perspectives/How-Smart-Cities-Can-Increase-Public-Transit-Ridership-Industry-Perspective.html

Zanghi, B. (2017, May 17). *How Smart Cities Can Increase Public Transit Ridership (Industry Perspective)*. Retrieved May 25, 2018, from http://www.govtech.com/fs/perspectives/how-smart-cities-can-increase-public-transit-ridership-industry-perspective.html