Lecture Notes in Electrical Engineering 988

Muhammad Amirul Abdullah · Ismail Mohd. Khairuddin · Ahmad Fakhri Ab. Nasir · Wan Hasbullah Mohd. Isa · Mohd. Azraai Mohd. Razman · Mohd. Azri Hizami Rasid · Sheikh Muhammad Hafiz Fahami Zainal · Barry Bentley · Pengcheng Liu *Editors*

Advances in Intelligent Manufacturing and Mechatronics

Selected Articles from the Innovative Manufacturing, Mechatronics & Materials Forum (iM3F 2022), Pahang, Malaysia

Springer

Lecture Notes in Electrical Engineering

Volume 988

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ISSN 1876-1100 ISSN 1876-1119 (electronic)
Lecture Notes in Electrical Engineering
ISBN 978-981-19-8702-1 ISBN 978-981-19-8703-8 (eBook)
https://doi.org/10.1007/978-981-19-8703-8

Preface

The third edition forum of The Innovative Manufacturing, Mechatronics & Materials Forum 2022 (iM3F 2022) organized by Universiti Malaysia Pahang through its Faculty of Manufacturing and Mechatronic Engineering Technology was held on 20 July 2022. The main field focuses on manufacturing, mechatronics as well as materials.

More than 141 submissions were received during iM3F 2022 and were reviewed in a single-blind manner, and 30 papers were advocated by the reviewers to be published in this Lecture Notes in Electrical Engineering. The editors would like to express their gratitude to all the authors who submitted their papers. The paper published in this proceeding has been thoroughly reviewed by the appointed technical review committee consists of various experts in the field of mechatronics engineering.

The conference had brought a new outlook on cutting-edge issues shared through keynote speeches by Assoc. Prof. Ir. Dr. Faiz Mohd Turan, Prof. Dr. Hasbullah Idris and Dr. Barry Bentley.

Finally, the editors hope that readers find this volume informative as we thank LNEE for undertaking this volume publication. We also would like to thank the conference organization staff and the International Program Committees' members for their hard work.

Pekan, Pahang, Malaysia
November 2022

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Automatic Vehicle Location (AVL): Evaluation on the Punctuality Index of City Public Bus Service

Haziman Zakaria, Diyana Kamarudin, Faiz Azizul, Mohammad Fitri Idrus, Nor Rokiah Hanum Md Haron, and Norhana Mohd Aripin

Abstract This study evaluates on-time bus service in 'City A', Malaysia using the punctuality index. Besides, the bus service reliability performance will also identify bus service punctuality characteristics for various operation conditions and routes in 'City A'. City 'A' has been selected as this city lacks commuter and rail services, unlike Kuala Lumpur and the Klang Valley; thus, City A's public bus service is in high demand. This article collected bus data using automatic vehicle location (AVL). Buses use SIM cards and mobile data networks to transmit location and time. GPS and fleet tracking system measure bus time and speed (FTS). Sampled bus system data was analysed to calculate punctuality indices for all routes. Different operating conditions affected bus punctuality. The punctuality index measures a stage bus's service quality. Finally, the result of the study can be used to evaluate and improve public bus service.

Keywords Automatic vehicle location · Fleet tracking system · Punctuality index · Transit capacity and quality of service manual (TCQSM)

1 Introduction

Public transportation reduces traffic congestion, saves money, and saves time. Most neighbourhood residents take public transportation to work, school, or shopping. Buses are popular due to their low cost and large service area [1]. 'City A' is one of

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M. A. Abdullah et al. (eds.), *Advances in Intelligent Manufacturing and Mechatronics*, Lecture Notes in Electrical Engineering 988,
https://doi.org/10.1007/978-981-19-8703-8_7

Peninsular Malaysia's fastest-growing commercial centres. The 2005 National Physical Plan identified 'City A' as Peninsular Malaysia's future growth centre [2]. Most bus companies in 'City A' are closing due to profit concerns and declining ridership. 'City bus services' were introduced in 'City A' in response to public transportation demand. There was no superior intercity service in 'City A' before 'city bus services'. Private bus companies around 'City A' ran at random times were late and provided ineffective services. Few people use this bus service and its accompanying services as a mode of transportation.

Even so, public transportation in most Malaysian cities, including 'City A', has not been able to compete with private cars. Most people would rather drive their car than take public transportation. Few of them say they are unhappy with how bad the public transportation services are. People did not use bus services because they did not have good amenities (like clean seats and air conditioning) and because being on time was important [3].

So, even though the government built Rapid KL, Rapid Penang, and Rapid Kuantan, people did not use public transportation. People who take public transportation are still few. If public transportation is not used much by many people, the bus company has to reduce service to save money. There is also what this means for people who usually take public transportation.

Sticking to its route is crucial for making sure customers are happy with its service. Even though buses often ran in 'City A', people had trouble getting where they needed to go because the buses were late. The fact that people on public buses are often uncomfortable makes them less reliable, making them less attractive than private cars. So, it is essential to find out if the public transportation system is working well enough. The output can be seen as a way for society to get the improvements it wants to make services better, meet needs, and make everyone happy.

Automatic vehicle location (AVL) systems allow authorities to track and observe moving targets surreptitiously. Using GPS satellite data, AVL systems can provide investigators with information on a vehicle's location, speed, and stopping point. One of Malaysia's integrated AVL systems is used in the 'City A' buses fleet tracking system. A complete AVL system uses GPS and other technologies (like CCTV video recording/online streaming and a passenger information system) to find buses and the mobile data network (MDN) to move data. The fleet tracking system keeps an eye on 'City A' buses. Every 15 s, it sends the location of each bus to the AVL centre. This information is then sent to the central server, which is used to improve service management and reliability, and the real-time passenger information system tells passengers.

Each cabin bus's on-board unit (OBU) is needed to find out where the bus is. It is a computer setup to get information about bus locations and events from different sources and store it. A GPS receiver on the roof of the bus sends the location of the vehicle every second. The system uses this information and algorithms for optimization and route/map matching to figure out exactly where the buses are.

The OBU keeps track of where a bus is along its route and what it is doing. It keeps track of things like how long the trip is and how many people are on it. Using a mobile data network, the OBU sends information about where the bus is to the master data

server (MDN). The location and activity data are then sent to the reporting central server through local area communications networks for post-processing, historical storage, and management reports.

One thing that affects the quality of bus service is how reliable it is. Reliability is a complicated idea that many things can define. The Malaysian Ministry of Transportation defines the reliability of public transportation as the number of morning rush-hour trips that are finished in less than an hour [4]. There is much evidence that shows how critical dependability is to the quality of transportation services [5]. Reliability can be described and judged from both the bus company's and the riders' points of view [6].

Several studies have also shown that bus service reliability is still an essential part of figuring out how good it is. Allen et al. [7] say that the reliability of the bus is vital for waiting time. They stressed how important it is for transportation companies to be on time and leave enough space between buses.

Accessibility is a measure of how easy it is to use transit to get around. It can be measured by the distance between transit stops or how long it takes to get from one stop to another. To find the right metric for public transportation, we need to find the ones that focus on how easy it is for people to get to transit where they live, where they work, and along routes that connect the two. As shown in the Table 1, two types of measures are made just for public transportation.

Using the transit capacity and quality of service manual (TCQSM), on-time performance and headway adherence can be used to measure dependability. Headway adherence means, amongst other things, how regular or even the time between bus trips is, how often trips are missed, and how many trips are passed up. People think that each bus has its schedule for when it will arrive at each bus stop. The quality of service framework for bus operations is shown in the Table 2. It shows the many ways that transit TCQSM can judge the quality of bus service.

Punctuality is measured by how much time has passed between the actual and expected arrival times. Timeliness is related to being on time. The headway evenness or adherence of interval service reliability criterion measures reliability in the same way a customer would [6].

Table 3 [8] shows how to make an index for how on-time bus operations are. Several types of punctuality indices were found. Each one was based on the number of bus stops and routes and included on-time performance and headway adherence.

In conclusion, the punctuality index (PI), which is also called 'on-time performance', is a metric that can be used in this study to measure reliability. The area chosen for this study is 'City A', a proliferating popular place for investment and tourism. Also, since bus companies have a monopoly, service reliability and integration are more accessible than in cities with more than one bus company. The specific research question that this study is trying to answer is:

RQ1: How well does the 'City A' bus service show up on time?
RQ2: How on time are the bus routes that 'City A' runs?
RQ3: Do you think there is a link between being on time and raining?
RQ4: How did other things affect how on-time the 'City A' bus service was?

2 Methodology

Automatic vehicle location (AVL) datasets were used to evaluate punctuality of bus route which collected through global positioning system (GPS) receiver inside on-board unit, which has been installed in 51 units buses. AVL dataset contains data for all trips that had scheduled departure time from the terminal between 5.20 a.m. and 11:00 p.m. The on-board unit is located in the driver's cabin and will transmit the data to bus control centre via mobile data network (MDN). The data will then be stored in fleet tracking system reporting database. In addition, the driver provided information on (1) the number of passengers alighting and boarding, (2) actual departure times and the scheduled and the actual, and (3) scheduled arrival times at each stop until the final destination. The passenger load, punctuality index, and travel time will be calculated using these data. Data collected is from 51 bus that covering 16 route and 580 trip daily for a period 7 month. The dataset was also divided into weekday and weekend to determine whether traffic condition has relationship with punctuality.

This study used CRISP-DM to analyse and process data of fleet tracking system (FTS) which contains punctuality, location, and the performance of the journey. CRISP-DM has 6 main phases (i.e. business understanding, data understanding, data preparation, modelling, evaluation, and deployment) which helps to narrow down the result and focus to the business user. The collected data was analysed to determine the transit capacity and quality of service manual standard (TCQSM), characteristics of bus service, and the punctuality index of each route.

To analyse the data, Microsoft Excel Analysis Tool was used to find the relationship between dependent variable (punctuality) and factors that affected the bus punctuality. The data is analysed by plotting the graph using Microsoft Excel Data.

3 Result

Punctuality refers to 5 min early or late in actual compare to scheduled time, and the punctuality percentage for the day has been calculated for each route. The quality of service was determined by comparing the punctuality value with TCQSM. The average punctuality performance percentage for 29 lines routes ranges from 37.1 to 91.8% with 76.4% on average. The monthly average punctuality route was recorded at 75.1% (June), 76.0% (July), 74.8% (August), 75.6% (September), 76.8% (October), 76.7% (November), and 78.4% (December). For level of service (LOS), only month of August was rated as F, whilst the rest of the month was rated as E. It is revealed that the average of punctuality index from June to December of 'City A' route is 76.4%, which is LOS E, means that every day there is one late transit service vehicle.

Using the percentage of punctuality service for each month, we can determine the level of service (LOS) rate for each route. According to the results, the lowest level of service (LOS) for most routes is C. Every week, more than one vehicle will be late for the average passenger at LOS 'C'. Line route which is always in Top 5 punctual

route from month June to December is line route 4002, followed by 3032, 2002, 4001, and 5001. Compressively, the punctuality indexes are not the same because traffic, driver, and passenger factors change randomly during the week. With a 52.4% punctuality rate, Route 200 is the most reliable route for being on time. For Route 401, the punctuality index is going down, whilst it changes throughout the month for other routes.

Bus route 400 is always on time. However, it varies greatly, which shows that the service is not always on time. Route 602 has the worst on-time performance because of traffic jams and many people taking it. These things make it take longer to get somewhere, so the bus might be late or miss the next trip. This situation proves that TCQSM's claim about the effect of traffic characteristics is valid [9]. Several drivers got to the station ahead of schedule and then left early or late. This behaviour goes against being on time and hurts your credibility. How on-time a public bus depends on the road conditions, the length of the route, the number of stops, the operations control strategies, the availability of the vehicle and crew, and the driving skills of the operators [10].

Hypothesis 1 measures the relationship between punctuality index and rainfall, and Fig. 1 shows the punctuality index versus the rainfall. Based on regression analysis from Fig. 1, bus operation punctuality has positive correlation with rainfall. When more rainfall, the punctuality also increases. This is could be when there is heavy rain, not many people are planning to going out using bus and also no traffic congestion. R2 is utilised as an indicator of fit quality. It indicates the number of points on the regression line. The result indicates that R2 is 0.83, indicating an excellent fit. In other words, the independent variables explain 83% of the dependent variables (y-values) over the independent variable (x-values). R2 is utilised as an indicator of fit quality. It indicates the number of points on the regression line. The result indicates that R2 is 0.83, indicating an excellent fit. In other words, the independent variables explain 83% of the dependent variables (y-values) over the independent variable (x-values). In addition, based on ANOVA regression analysis output, the significance F value is 0.004 which is less than 0.05 (5%). Figure 1 shows the result is reliable and statistically significant.

Second hypothesis measures the relationship between punctuality index and ridership. The one week punctuality data is use on this test to analyse the effect of traffic condition to the punctuality. P-value is the probability value in hypothesis testing to accept or reject null hypothesis. The alpha values used at 0.05 or 5% significant level. Based on t-test, one-tailed p-value = 0.004 and two-tailed p-value = 0.008. If p-value is less than 0.05, it suggests a significant differences between punctuality on weekend and weekday. Based on the result, Fig. 2 shows that the punctuality index on weekend is statistically higher than weekday.

Hypothesis 3 measures the relationship between punctuality index and ridership. Based on regression analysis from Fig. 3, the correlation coefficient result is 0.19 which shows a very weak linear relationship. So, the number of riders seems to have a negligible effect on the punctuality index. In addition, significance F value is 0.479 which is higher than 0.05 (5%) and resulted not significant between ridership and punctuality.

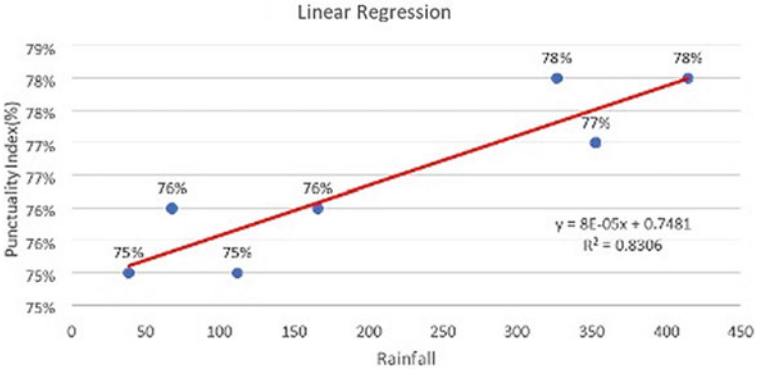

Fig. 1 Punctuality index (%) versus rainfall

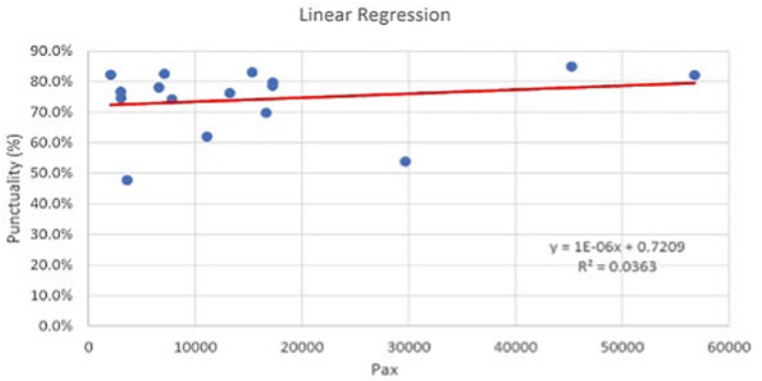

Fig. 2 Punctuality index (%) versus ridership

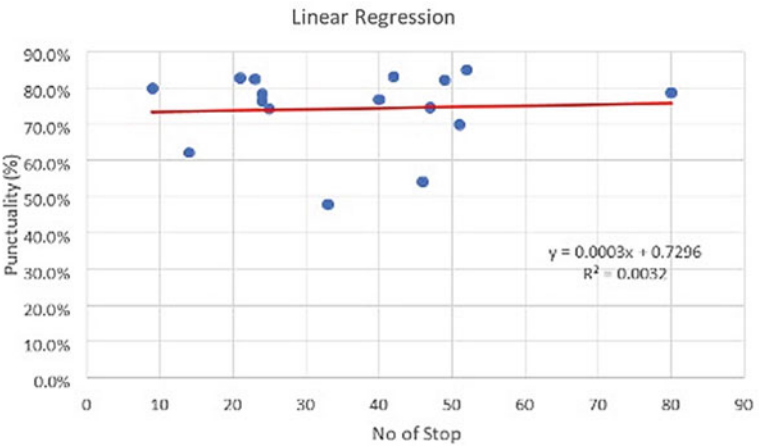

Fig. 3 Punctuality index (%) versus number of stops

The fourth hypothesis measures the relationship between punctuality index and number of stops. Based on regression analysis, the result of correlation coefficient is 0.05 showing no linear relationship since it is close to 0. As a result, the punctuality index has no significant different with the number of stops. Additionally, the significance F value is 0.83 which is higher than 0.05 (5%) and significantly no correlation.

4 Discussion

From a passenger's point of view, reliability is the ability of a system to stick to a schedule or keep regular headways and a predictable trip time. It is also known as 'arrival as scheduled' [11]. Unexpected or unscheduled vehicle arrivals make it hard to keep a steady pace or let vehicles pass through stations regularly [12]. There are some stops or stations where buses may be late. Consequently, they often leave later than planned. Because of these things, the bus service is not very reliable. Two important part that will help passenger when dealing with bus delay is customer-focussed attitude from bus drivers and fast information.

Firstly, people in 'City A' complained that buses were always late and long wait times on some bus routes. They said that the company was running out of buses because so many of them were broken. Since there are fewer buses on some routes, the difference in headways is more considerable. Customers started to use taxis and e-hailing to get where they needed to go. Over the past year, the number of people taking the bus in 'City A' has steadily decreased. However, people on several routes were happy with how on-time and consistent the service was.

Secondly, customers know that the buses leave on time from what they have seen on the schedule. Because there are not enough buses, there is still a long wait between buses. Because there is much demand, some buses may leave before their scheduled time. A bus might be late if many kids wait at a station or frequently stop. Most people who take the bus are students, so the schedules are based on when they go to school.

Thirdly is driver behaviour. When the bus was full, some of the drivers left before they were supposed to. Because of this, people had to wait longer for the next trip. This problem will result in more people on board for the next trip. On the second trip, the speed was slowed because the bus would frequently stop to load and unload. For example, a bus trip that was supposed to leave at 12:30 p.m. left 30 min early because so many people were on it. The following bus will not come until 2:00 p.m. for those who arrive in the afternoon. These people will have to wait longer and will be added to the people on the 2 p.m. flight. People who cannot afford to wait for so long might choose a different way to get around, making public transportation less appealing in the long run.

Lastly is bus condition. The excellent condition bus must be in good shape and has 30 seats that recline and 34 places to stand air-conditioned. There are two automatic doors in the front and middle of the bus during rush hours that help people get on

and off. All buses use electronic ticketing machines (ETMs) to sell tickets. These machines print out a small piece of paper, and you can pay with cash or a credit card.

Most bus riders know that a bus's ability to arrive on time depends on traffic, road conditions, and things that cannot be helped, like accidents. On the other hand, passengers think that bus companies should focus on things they can control to cut down on delays. Bus delays can cause people to be late to work, pick up their kids late, or miss medical or other appointments. When delays and other problems happen, bus customers will benefit from two changes: getting necessary information and having bus drivers who care more about their customers. When the bus is late, people feel helpless. Many people on the plane think they cannot find out what is going on. 'Sometimes, it is hard to decide whether to stay or leave at bus stops', said one passenger. There is a big difference between what passengers have experienced and what they want from bus drivers. During delays and other problems, passengers want bus drivers to act as the company's customer service representative by giving information, showing empathy, and apologising. To close this gap, we need to teach drivers how to provide good customer service and look for ways to reduce the stress on drivers by getting them to talk to passengers directly.

To a lesser extent, planned roadwork and typical peak traffic congestion are seen by passengers as delays or disruptions, as are severe weather, accidents, emergency roadwork, and technical problems with the bus. Passengers also complain about delays caused by buses leaving early, driving by stops without picking up passengers, taking too long to buy tickets, and what they see as poorly designed schedules that cause services to 'cluster'. Some examples of disruptions the industry could expect were delays and changes to services. Some roads were closed or detoured because of roadwork or important local events. Traffic jams (especially during rush hours) and planned road work were the most common reasons for delays or other problems.

Passengers also mentioned other things they think cause problems and delays with bus service. These had to do with the bus's business, the driver, or other people on the bus most of the time.

(1) Buses often stop for short periods along the way because the driver needs a break or because they need to switch drivers, though this is not always the case. Passengers do not always know what is going on or why. Furthermore, the explanation is not always thought to make sense even when they do the problem. (2) Buses depart early from the schedule. Participants said that the driver might not have seen all of the people waiting for their specific vehicle and that they had seen buses drive by bus stops without stopping whilst people were waiting. (3) People who take too long to get on or pay are doing so because many people are getting on simultaneously, and they need to get payment change. (4) A human error happens, for example, is a driver who takes the wrong turn. Some of the people who took part in the study thought that timetables are not always set up well, which causes services to be grouped together and then spread out. This problem is especially true when more than one company serves the same area.

The drivers who took part in this study said that traffic jams, road closures, bad weather, accidents, mechanical problems, and passengers who were hard to deal with were all significant sources of disruption. When customers' trips are delayed or

have other problems, drivers often feel sorry for them, even if the customers do not know it. Drivers do not want to give accurate information if the situation is likely to change, so they do not. This situation means that the information is not correct, which could hurt them in the future. This problem is a real worry, but the people who took part in this study said they were aware of how road travel affects the ability of bus companies and drivers to give accurate information. Passengers thought that having some information was better than having none, as long as it was based on the best information that was available.

Both passengers and drivers suggested other ways to deal with delays and other problems and keep passengers informed. (1) Roadwork or events in the area that close roads or cause traffic jams. Local governments and bus companies need to talk to each other more about scheduling maintenance that causes minor inconveniences. Drivers and passengers, for example, would prefer that work on a stretch of road not be done all at once but instead at different times. Also, they would rather take a different route around road construction than drive through it. (2) Traffic jams and temporary traffic lights are a problem. Some passengers and drivers think that the lights could be timed better to give cars enough time to pass before letting traffic flow in the other direction. Several passengers and drivers asked that timetables include a 'rush-hour contingency' to make peak-hour schedules more realistic. Bus priority lanes were supported by drivers everywhere because they saw how well they worked where they were already in place. (3) Bus has mechanical issues. Some passengers think that technical problems are unacceptable because cars should be well-kept (whilst it might be naive to think nothing will ever break down, this is a genuine perception that bus companies need to be aware of). (4) Boarding time too long for one customer. Most passengers like new ways to buy tickets, like smartcards, which make the process faster. Many customers think that there should be more buses at certain times to reduce the number of people waiting to get on, which causes delays. In particular, these passengers think that more specialised school buses are needed so that other passengers do not have to wait when school is in session.

5 Conclusion

Punctuality is one of the most important ways to measure how well a bus service works. 76.4% of buses on the level of service E route arrive on time from the analysis. In December, Route 400 has a 91.8% (LOS B) punctuality index, whilst in June, it has a 37.1% (LOS F) index. These results show that the 'City A' bus service needs to get better at being on time.

The punctuality index ranges from 37.1 to 91.8%, with 76.4.8%. Statistical T-test result shows that punctuality on weekends is statistically higher than on weekdays. P-value with one tail is 0.004164, and P-value with two tails is 0.008328. In both cases, P-value is less than the alpha value, i.e. 0.05, thus can reject the null and assume a significant difference between punctuality on weekends and weekdays.

Thus from the result, it can be conclude that a common reason for unreliable service is that too many people are on the route. It makes travel times longer, makes bus rides unpredictable, raises costs, makes people less likely to trust buses, and reinforces negative ideas about them.

As an effect of rainfall on punctuality, based on regression analysis output, punctuality of bus operation has a positive correlation with the rainfall. This positive correlation could be when there is heavy rain, not many people plan to go out using the bus. When it is raining, many people will choose to travel by car because it is more comfortable.

Based on regression analysis output of effect ridership towards punctuality, the result correlation coefficient is 0.19 means a fragile linear relationship. The punctuality index seems to increase with the number of ridership slightly. Several things effect this result, such as traffic, weather, dwell time, and the number of people getting on or off the bus, can affect how well a transit bus system works along its route. Dwell time is the amount of time a vehicle stops for passenger service. It includes the time between when the doors opened and when they closed. The method of payment can affect how long the bus stays in one place [13, 14]. Paying fares affect how long a bus stays in one place. City A bus will take both cash and credit cards. Since the bus only has one driver and no helper, they only can provide limited ways to pay. The driver must be the one to make money and give out tickets. Customers have to wait in line at the door, making boarding take longer.

As an effect of the number of stops towards punctuality, regression analysis output indicates that the correlation coefficient is 0.05 means no linear relationship since it is very close to 0. A study suggested that the platform crowding pattern significantly affects dwell time [15].

It makes it hard for people to move around and hard to see approaching buses. Also, when more people are waiting on the platform, there is a higher chance that more people will get on the same bus. This condition causes bus stops to get crowded, and people have to wait longer for the bus. Also, if the station is full of people, the bus may not be able to see passenger waiting. This problem could make people slower to react when the regular bus comes, which would make them stay longer.

The study says that the punctuality index can measure how reliable mixed-traffic fixed-route bus services are [16]. Punctuality index studies are often used to measure how well bus routes and bus companies serve their customers. If bus companies could lose government subsidies based on how on time they were, they would try to improve how on time they were [17]. When figuring out how reliable public bus service is, the punctuality index is just one of many things to think about.

More factors should be looked at to expand the scope of bus reliability research, such as how often or how often buses run. In addition, improving punctuality is helpful to passengers to reduce the waiting time at bus stops or make reasonable travel arrangements before making a trip. However, for this to be effective, the information provided to passengers should be reliable and accurate.

Acknowledgements This research is funded by UMP PGRS 2003162: Determinant of Malaysia SME Innovation Action Based on The Triple Helix Model.

Appendix

Table 1 Type of metrics from guide to sustainable transportation performance measures, EPA

Type of metrics	Description	Metrics identified
Distance to transit stops	These metrics capture the main office commuters based on locations, population, trip origins, or trip destinations within a certain radius of a transit stop	(1) Per cent of daily/peak period trips (origins and destinations) starting or ending within 100 m of a transit stop. (2) Per cent of population and employment within 100 m of transit
Destinations accessible by transit	These metrics capture not just the accessibility of transit stops, but the connection that transit provides to various destinations	(1) Number of households within a 30-min transit ride of major employment centres/city centre. (2) Percentage of work and education trips accessible in less than 30 min transit travel time. (3) Percentage of workforce that can reach their workplace by transit within one hour with no more than one transfer

Table 2 Quality of service framework

	Service measure		
	Transit stops	Route segments	System
Availability	Frequency	Hours of service	Service coverage
Comfort and convenience	Passenger load	Reliability; (1) on-time performance and (2) headway adherence	Transit-auto travel time

Table 3 Punctuality indexes

Punctuality index	Description
P1	Shows how much time has passed between the actual arrival time and the time that was planned (adherence)
P2	Shows how much time has passed between the actual headway and the planned one (regularity) destinations
P3	An index that shows how long it takes between the average headway of a day and the average headway of the next bus (evenness)

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