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On-Time Performance and Service Regularity of Stage Buses in Mixed Traffic

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***Abstract*—**Stage bus operated in the mixed traffic might always meet many problems about low quality and reliability of services. The low quality and reliability of bus service can make the system not attractive and directly reduce the interest of using bus service. This paper presents the result of field investigation and analysis of on-time performance and service regularity of stage bus in mixed traffic. Data for analysis was collected from the field by on-board observation along the Ipoh-Lumut corridor in Perak, Malaysia. From analysis and discussion, it can be concluded that on-time performance and service regularity varies depend on station, typical day, time period, operation characteristics of bus and characteristics of traffic. The on-time performance and service regularity of stage bus in mixed traffic can be derived by using data collected by on-board survey. It is clear that on-time performance and service regularity of the existing stage bus system was low.

***Keywords*—**mixed traffic, on-time performance, service regularity, stage bus

I. Introduction

BAD reliability measures of bus services are the worse among other measures because (a) they can cause the bus not attractive to customers and give a distorted view of bus service, and (b) they waste valuable resources that may be better used elsewhere. In other side, good reliability measures can provide customers with a realistic picture of their transit experience and knowledge in using public transport services.

There are many problems faced by regulator, operator and also users in using the bus service provided in rural area, such as bus system in Ipoh-Lumut corridor. The problems include such as limitation of facilities, low quality buses, inconvenient of fleets, low passenger trips, long waiting time and bad view of bus services. Long waiting time for a bus is very common and it makes the system not attractive to passengers.

Two indicators that measure different aspects of service performance experienced by customers can be used to represent the reliability of bus services. Those are end route on-time performance and service regularity. Based on above explained facts, it is necessary to investigate and analyze the current bus system to especially obtain the two measures of reliability - on-time performance and service regularity. The investigation then named "On-Time Performance and Service Regularity of Stage Buses in Mixed Traffic".

On-time performance is an important reliability measure of bus service for the customer riding on the bus and for the customer waiting at a bus stop during a time period or headways service. Regularity is a measurement of consistency of bus service to ensure that the bus operator is providing reliable service. Stage bus is a bus system which regularly serving passengers with stopping anywhere along certain route. Mixed traffic is road traffic at which bus operated along the route without separation and bus is kept apart of whole traffic. Others, mixed traffic is also characterized that there are no specific separation control between motorized vehicles and non-motorized. There are also light and heavy vehicles which are mixed.

Stage bus operated in mixed traffic always meet many problems about low quality and reliability of services. The low quality and reliability of bus service can make the system not attractive and directly reduce the interest of using bus service. The observation and recommendations provided were offered as the resources to operator and regulator for consideration in enhancing the efficiency and effectiveness of bus service delivery and operations. In addition, the results also can be a guide or information to passengers with experience on using bus service.

II. Theoretical Background

A. Terminal, Bus Stop and the Route

Terminal is a point of place at the end of route at which transit vehicle may arrive and depart service or remain stationary for a few moments for layover/recovery. It is important that the layover/recovery time is provided at the terminal point. It is used for resting, administrative purposes and for maintaining proper headways. Terminal is also named station. There are normally two terminal points each linear route, one at each end. As mentioned in TRB [1], bus stop is the first point of contact between the passenger and the bus service. The spacing, location, design, and operation of bus stops significantly influence transit system performance and customer satisfaction.

Bus route is a specific physical path that a transit vehicle

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follows [2-3]. Generally, there are types of route, such as basic end-to-end route, loop route and branches route. In the end-to-end route configuration with bi-directional service, there are two terminals located at each end of the road.

B. Performance of Bus Service

Assessing the current status of bus operating systems is necessary to investigate their performance. Current bus system should be frequently checked as they are old, outdated and are not conducive for effective and efficient working conditions. Is there currently a significant level of bus service during of whole operating period? Is the current number of bus stops adequate in serving passengers based on the segment along the route?

Generally, there are some important performances of bus service which can be used to measures the reliability of bus service. Two performances discussed in this paper are on-time performance and service regularity. Many measures of bus service performance were continuously appraised by transport engineers. For this interest, some basic terminologies within bus service are briefly explained [3].

Operating speed is the average speed at which a transit vehicle can traverse the route in question, including intermediate stops. Headway is the time that should elapse between consecutive buses arriving at stations or terminal points. Schedule is the temporal path that a transit vehicle follows, or a listing of times at which the transit vehicle should be located at various places. Travel time or running time is the portion of the cycle time that is spent traveling, not in layover/recovery. Cycle time is the total time required to complete a full cycle. The cycle time includes the running time and the layover/recovery time. Layover/recovery time is the time that transit vehicle should remain stationary at each terminal point. The layover/recovery time is used for resting, administrative purposes, and for maintaining proper headways.

It is important to improve the bus system service for customers and operations management. It is needed to ensure that the fundamental basis of an adequate and reliable bus fleet were available. For example, it is necessary to establish performance measures that evaluate bus operations from a customer stand point as follows:

1. Percentage of buses dispatched from bus depots on-time.
2. Percentage of buses on-time on route where frequency is greater than 30 minutes (i.e. on-time being 5 minute ahead to 5 minutes late).
3. Percentage of the low volume bus route (frequency of more than 10 minutes), etc.

C. Definition of On-Time Performance

On-time performance is the percentage of passing scheduled trips divided by the total number of scheduled trips available for analysis [4]. On-time performance is important for the customer riding on the bus and for the customer waiting at a stop during a time period with large bead-ways. Run numbers of buses are associated with specific bus operators. Each trip or scheduled depart time is analyzed only once and either passes or fails. On-time performance tracks the schedule adherence of specific buses, buses in this category count against on-time performance.

D. Definition of Service Regularity

Service regularity represents the experience of the customer waiting for a bus, expecting service every a time (a few minute). This measurement is especially important for high-volume routes with tight headways. The regularity measure addresses customers' concerns about how long he or she must wait from the time they arrive at the stop until the depart time of the next bus. Regularity also measures consistency of service. A customer who sees a bus appear regularly is reassured that the transit agency is providing reliable service [4].

To analyze regularity, scheduled intervals are matched with actual interval. Each scheduled interval is used only once for analysis and whether passes or fails. The number of passing scheduled intervals divided by the total number of scheduled intervals available for analysis generates the regularity result, which is presented as the percentage of passing scheduled intervals. In ideal case, both on-time performance and regularity are 100 percent.

E. Timetable and Bus Fleets

A timetable or schedule is an organized list, usually set out in tabular form, providing information about a series of arranged events: in particular, the time at which it is planned these events will take place. From data in Perak Roadways Sdn. Bhd. [5], the timetable for bus service in Ipoh-Lumut corridor was showed in Table I.

TABLE I
DEPARTURE OF BUS (SCHEDULED)

		Vehicle Block						
		1	2	3	4	5	6	7
Shift 1	Leave Ipoh	7:00	7:30	8:00	8:30	9:00	9:30	10:00
	Arrive Lumut	8:50	9:20	9:50	10:20	10:50	11:20	11:50
	Leave Lumut	9:00	9:30	10:00	10:30	11:00	11:30	12:00
	Arrive Ipoh	10:50	11:20	11:50	12:20	12:50	13:20	13:50
Shift 2	Leave Ipoh	11:00	12:00	13:00	13:30	14:00	14:30	15:00
	Arrive Lumut	12:50	13:50	14:50	15:20	15:50	16:20	16:50
	Leave Lumut	13:00	14:00	15:00	15:30	16:00	16:30	17:00
	Arrive Ipoh	14:50	15:50	16:50	17:20	17:50	18:20	18:50
Shift 3	Leave Ipoh	16:00	17:00	17:30	18:00	-	19:00	19:30
	Arrive Lumut	17:50	18:50	19:20	19:50	-	20:50	21:20
	Leave Lumut	18:00	19:00	19:50	6:20	-	7:00	7:30
	Arrive Ipoh	19:50	20:50	21:10	8:10	-	8:50	9:20

Source: Perak Roadways Sdn. Bhd. [5]

Table II displayed that the fleet appeared old (average age 13.9 with many buses over maximum age of 15 years). The old buses caused low quality bus service then they were not attractive for passengers. In spite of low quality, the old busses need high operation and maintenance cost. The operator needed additional budget to address increasing needs for painting, cleaning and repairs/replacements to on-board equipment. Malaysia Commercial Vehicle Licensing Board

(LPKP) [6] decided the maximum operating life of public services vehicle license for stage bus is 15 years. It is longer than 10 years for express bus. In other side, the aspect of safety is also decreased due to low quality of bus fleets. The evidence, the operators could not provide a safe bus service to its customers. A number of fleets observed exceeded the operating life limit.

TABLE II
CHARACTERISTICS OF BUS FLEETS IN IPOH-LUMUT ROUTE

Characteristics of Fleets		Description
1. Number of bus		9 fleets
2. Length of route		86 km
3. Number of trips per day		6 trips/day
4. Year of production (oldest)		1990
5. Year of production (newest)		2001
6. The age		8-19 years
7. The age of operated/registered		6-19 years
8. Mileage (km per bus):	2004	123,840
	2005	148,608
	2006	173,376

Source: Perak Roadways Sdn. Bhd. [5]

III. MATERIAL AND METHODS

A. Location and Data Resources

To collect the data for analysis, the bus service operated in Ipoh-Lumut corridor had been chose, due to the low quality of existing bus service. In addition, Ipoh-Lumut corridor as a strategic key feature of Perak road network is growing with many potential land uses. The bus operator which operated buses in this route also provided some respective data to analysis. Other secondary data were collected from related private or government bodies, such as map, project report, road traffic volume, statistics, and Perak Master Plan.

B. Route Observation

Fig. 1 depicted the time-distance relationship which is fundamental in understanding of bus operation. It was basic necessity for planning, organizing, actuating and controlling in public transportation, no exception for bus service system management.

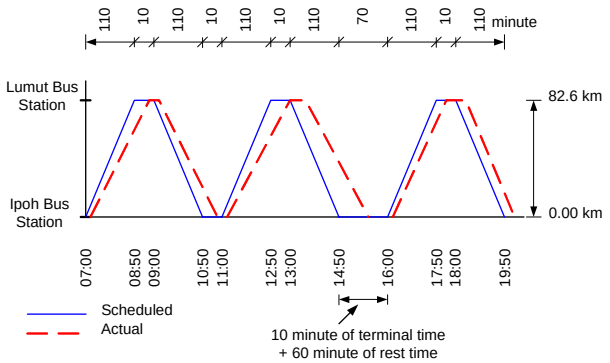


Fig. 1 Time-distance diagram of bus operation schedule

Route observation is necessary to identify the point of location where buses follow along the route from a start point (terminal) to end point (terminal), length of route, travel time and other features (i.e. land use of road side). The route was tracked by using handheld GPS (Etrex LEGEND, Garmin). Fig. 2 described the layout of bus operation schedule shift 2, round trips along the 82.6 km route.

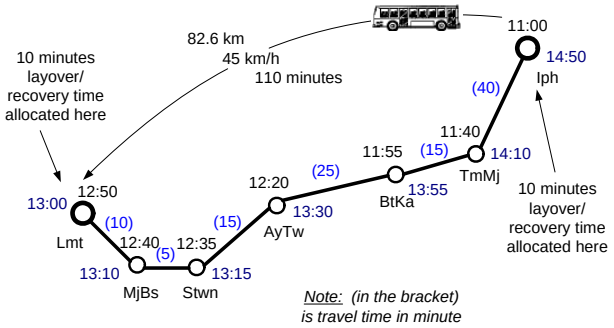


Fig. 2 Layout of bus operation schedule

C. Boarding and Alighting of Passengers

The number of data points used for analysis was 12 months x 2 days/month x 2 trips per day = 48 trips per year. The data used is primarily collected from Perak Roadways's 14-hour weekday service.

Boarding and alighting passengers was obtained by onboard survey. Previously, the route was identified by using handheld GPS (Etrex LEGEND, Garmin). The points identified between two main bus station (Ipoh and Lumut) indicated the place where passenger boarding and alighting.

The observer situated inside the bus records the number of passengers boarding or alighting at points, but he did not need to record himself as passenger. At the same time, observer also record or enter code of the point into the GPS at which passengers get on or get off the bus. This task was conducted repeatedly between the two terminals (start and end points) during operating period, but the observer did not need to take the same bus. Since intercity buses have one door for passengers get on or get off, therefore only one observer was required to be located at the front door.

D. Analysis of On-time Performance and Service Regularity

On-time performance was calculated by dividing number of trips departing between 0 and 5 minute after their scheduled departure time by total number of trips from all scheduled time points. For this purpose, it was distinguished between main bus stations and bus stops. For example, if the headways are 60 minutes and an 11:00 bus departs at 11:02, it was categorized into on-time performance. Table III clearly described the method to analysis the service regularity of bus service.

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TABLE III
NUMBER OF TRIPS PASSING, FAILING AND AUTO FAIL THE REGULARITY INTERVAL

Example	Schedule Depart	Actual Depart	Scheduled Interval	Actual Interval	Within range*)	Pass? **)
1	11:00	11:05	60	60	Yes	Yes
	12:00	12:05				
2	11:00	11:00	60	65	Yes	Yes
	12:00	12:05				
3	11:00	11:05	60	75	Yes	No = Fail
	12:00	12:20				
4	11:00	09:58	60	127	No	Auto Fail = No
	12:00	12:05				

Note: *) The acceptable range is 10:00 to 12:00, **) Passing interval -5 to 5 (10 minute)
Auto fail: because there are no bus departs between the acceptable range of 10:00 and 12:00. Therefore, this interval is never analyzed – it automatically fails and counts against regularity.

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IV. RESULTS AND DISCUSSION

A. Travel Time and Schedule Delay

Table IV showed that travel time of round trips during workday and weekend every month had its average of more than 3:40 as it was scheduled. Almost the cycle times during workday and weekend were also exceed 3:40, except cycle time during weekend on March was less than 3:40. It was because the observed buses rarely stopped for passengers boarding and alighting. The average travel time during workday was higher than weekend as buses often stopped for passengers boarding and alighting (see Table V). The phenomena were observed for trip from Lumut to Ipoh rather than Ipoh to Lumut.

TABLE IV
MONTHLY BUS TRAVEL TIME (IN HOUR) BY TYPICAL DAY IN 2007

Month	Workday	Weekend	Average
Jan	4.13	4.12	4.13
Feb	3.92	3.7	3.81
Mar	4.32	3.58	3.95
Apr	4.15	4.07	4.11
May	3.9	3.8	3.85
Jun	3.8	3.95	3.88
Jul	3.95	4.13	4.04
Aug	3.97	3.97	3.97
Sep	3.97	4.18	4.08
Oct	3.78	3.95	3.87
Nov	4.07	3.9	3.98
Dec	4.13	4.08	4.11
Average	4.01	3.95	3.98

TABLE V
BUS TRAVEL TIME (IN HOUR) BY DIRECTION AND TYPICAL DAY

Typical Day	Ipoh to Lumut	Lumut to Ipoh	Average	Round trip
Workday	1.93	2.07	2.00	4.01
Weekend	1.97	1.98	1.97	3.95
Average	1.95	2.02	1.98	3.98

Schedule delay in term of bus service is refers to a difference between a desired time of arrival or departure and the actual time. Delay also can refer to a difference in either the early or late direction. From Table VI, for example, in the context of bus service, if a bus is scheduled to depart from a stop (Ipoh) at 60-minute intervals (e.g. 11:00, 12:00, 13:00) and a person wishes to begin his journey between those intervals (e.g. at 11:09), he incur a schedule delay through having to retime his departure from the desired 11:09 point to the bus departure time of 12:00. The average delay of departure at Ipoh main bus station was lower than that at Lumut main bus station. Also, it could be seen that delays of arrival at anywhere were much higher than others.

TABLE VI
SCHEDULE, ACTUAL TIME AND DELAY (IN MINUTE) AT THE MAIN BUS STATION

Type	Depart Ipoh	Arrive Lumut	Depart Lumut	Arrive Ipoh
Schedule	11:00	12:50	13:00	14:50
Actual	11:09	13:05	13:08	15:11
		Delay (minute)		
Workday	10	15	7	22
Weekend	7	16	10	20
Average of delay	9	15	8	21

Fig. 3 displayed the high fluctuation of actual departure time at both main bus stations. Based on facts observed, it might firstly because of the difficulties on maintaining headway along the trip in mixed traffic, the second by many stops for serving passengers and the third by the needs for layover/recovery time in terminal. Distribution of delay from January to December 2007 was not adequate to state generalization of monthly period and delay relationship.

B. Operating Speed in Mixed Traffic

A significant characteristic of mixed traffic discussed here was the dispersion of operating speed along the assessed route. Fig. 4 visualized distribution of operating speed between Ipoh to Lumut and Lumut to Ipoh direction. Condition of mixed traffic could affect the operating speed of bus service. Line graph of Ipoh to Lumut direction showed that the operating speed was concentrated closely the mean, but that of Lumut to Ipoh direction was highly dispersed. Table VII shows the statistics of operating speed. Fig. 5 described clearly the average and standard deviation of operating speed each segment along the route.

TABLE VII
STATISTICS OF OPERATING SPEED

	Direction	Min Speed (km/h)	Max Speed (km/h)	% of Total Trips within speed of 31-55 km/h	Average (km/h)	Std. Dev (km/h)	Variation (%)
Workday	Iph to Lmt	31.4	67.8	94	43.4	8.2	18.9
	Lmt to Iph	16.1	67.8	70	38.4	10.0	26.0
Weekend	Iph to Lmt	26.4	56.6	94	42.3	7.2	17.0
	Lmt to Iph	14.3	56.5	70	40.4	10.3	25.6
Average	Iph to Lmt	26.4	67.8	94	42.8	7.7	18.0
	Lmt to Iph	14.3	67.8	70	39.4	10.2	25.8
	Two ways	20.4	67.8	82	41.1	9.0	21.9

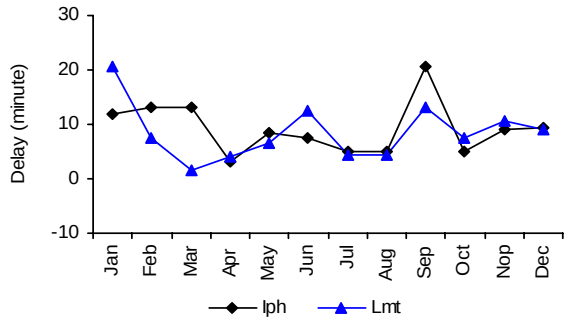


Fig. 3 Average delay of departure from January to December 2007

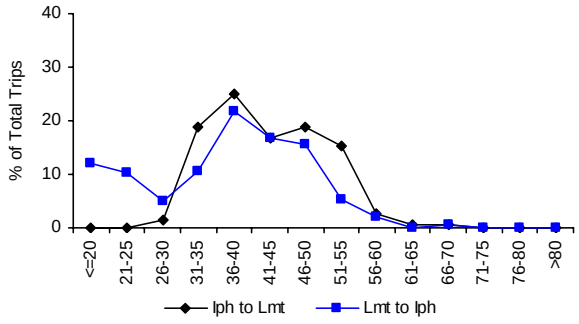
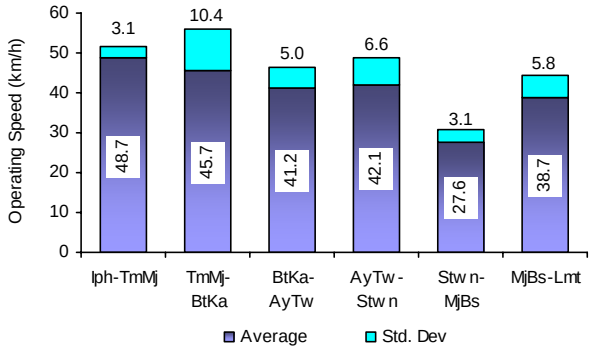
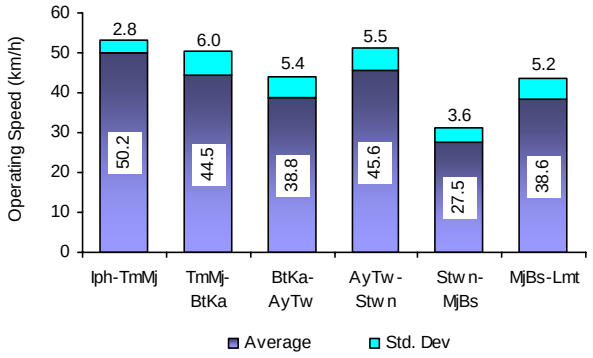


Fig. 4 Distribution of operating speed along the bus route



(a) workday



(b) weekend

Fig. 5 Average and standard deviation of operating speed along the bus route

C. *Stage Bus Service Characteristics*

The percentage of number of stop was analyzed to get the information how often bus get stop for serving get on and/or get off passengers. Anywhere there were passengers the stage bus would stop for serving passengers since it was possible. Hence, the stage bus could stop anywhere along the route, consecutively resulted the longer total cycle time. There were extreme differences between two segments, Sitiawan – Manjung bus station and Ipoh bus station – Taman Maju (see Table VIII). Ipoh bus station – Taman Maju segment has low rate/intensity of stop (0.09 per km), means that it has high average distance for stopping (longer stop distance). It was also clear how the Sitiawan – Manjung bus station segment could be explained, with 1.21 number of stops per km. For both directions, for average length of 2 km bus would stop for picking up or dropping passengers.

D. *Stage Bus Service Characteristics*

On-time performance was analyzed with categorizing the stations into two groups, such as main bus stations and bus stops at which bus stop for boarding and alighting along the route. Main bus station consisted of Ipoh bus station and Lumut bus station. Bus stop is a point comprised physical building as bus stop or anywhere bus stopping for boarding and alighting during the service. It was assume to be approximately 10% of scheduled interval (60 minutes) after departure time for determination of whether a bus depart is on-time or late. Hence, the accepted interval for on-time departure is within 0-5 minute interval.

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TABLE VIII
NUMBER OF STOPPING AS THE CHARACTERISTICS OF STAGE BUS IN MIXED TRAFFIC

No	Segment	Length of Segment	Ave. No of Stopping	% Stopping	No of Stopping / km	Average Length per Stopping
	a. Ipoh to Lumut direction:					
1	IphBs-TmMj	30.2	2.71	9.50	0.09	11.15
2	TmMj-BtKa	11.3	4.46	15.64	0.39	2.53
3	BtKa-AyTw	17.6	8.29	29.09	0.47	2.12
4	AyTw-Stwn	11.9	4.75	16.67	0.40	2.51
5	Stwn-MjBs	4.3	5.21	18.27	1.21	0.83
6	MjBs-LmtBs	7.3	3.08	10.82	0.42	2.37
	Total/average	82.6	28.50	100	0.50	2.01
	b. Lumut to Ipoh direction:					
6	LmtBs-MjBs	7.3	1.79	6.02	0.25	4.07
5	MjBs-Stwn	4.3	4.17	14.01	0.97	1.03
4	Stwn-AyTw	11.9	4.58	15.41	0.39	2.60
3	AyTw-BtKa	17.6	8.54	28.71	0.49	2.06
2	BtKa-TmMj	11.3	6.67	22.41	0.59	1.70
1	TmMj-IphBs	30.2	4.00	13.45	0.13	7.55
	Total/average	82.6	29.75	100	0.47	2.14

Fig. 6 indicated that there was a difference of on-time performance at bus stops between Lumut to Ipoh and Ipoh to Lumut directions. As on-time performance of 0-5 minutes after departure time is considered, there were 13% of total trips from Ipoh to Lumut and 9% of total trips from Lumut to Ipoh. The ideal on-time performance is 100%, where higher percentage indicates better performance of bus service. See also Table IX for detail description. The comparison of on-time performance between main bus stations and bus stops were also displayed in Fig. 7. On-time performance at main bus stations was better than of that at bus stops. That is because of there was layover/recovery time available at main bus station for starting and ending of trips. Fig. 8 shows the characteristic of monthly distribution of on-time performance in 2007.

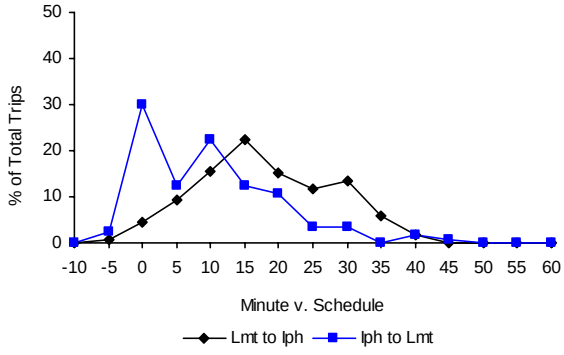


Fig. 6 On-time performance distribution at bus stops each direction

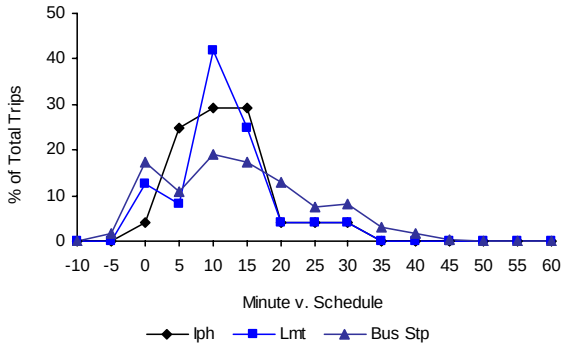


Fig. 7 On-time performance distribution at bus station and bus stop

TABLE IX
CUMULATIVE DISTRIBUTION OF TOTAL TRIPS BASED ON INTERVAL TIME TO DEPARTURE

Station	Minute versus Schedule								
	< -5	-5-0	0-5	0-10	0-15	0-20	0-25	0-30	>30
Ipoh bus sta	0	4	25	54	83	88	92	96	0
Lumut bus sta	0	13	8	50	75	79	83	88	0
Iph to Lmt bus stop	3	30	13	35	48	58	62	65	3
Lmt to Iph bus stop	1	4	9	25	47	62	74	87	8
Average	2	17	11	30	47	60	68	76	5

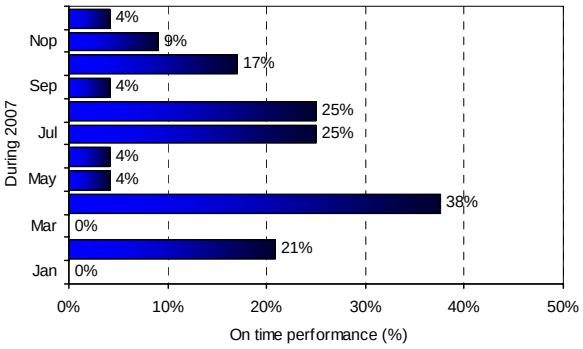


Fig. 8 Monthly on-time performance in 2007

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E. Regularity of Bus Service

The discussion about service regularity would be clearly guided by looking at the Table X. Assumption had been taken to analyze service regularity of bus service. It was considered that regularity was determined by using the passing interval from -5 to +5 minutes (5 minutes ahead and after schedule of departure time). If the actual interval met within schedule interval so that actual departure was categorized into passing, otherwise it would be in fail category.

In the analysis of service regularity, it was also important to decide whether the actual departure was in acceptable range. Acceptable range was determined by using one previous interval time (for lower limit) and one next interval time (for upper limit). For the case, departure time was 11:00 so that the acceptable range is 10:00 to 12:00. Hence, auto fail was because there were no bus departs between the acceptable range of 10:00 and 12:00. Therefore, this interval is never analyzed – it automatically fails and counts against regularity.

Table X showed the distribution of regularity at each station. The total percentage of passing as indicator of regularity falls into low percentage. The regularity at Ipoh bus station, Lumut bus station and all bus stops were 29.2%, 20.8% and 29.7%, respectively. All regularity values were relatively around 30% which they were at the same route. Monthly distribution of service regularity had not indicated any specific state yet, as there was not monitored annually (see Table XI). Table XII just tabulate the summary of early, on-time and late in term of percentage of total trips, meanwhile the service regularity was percentage of actual interval passing to total scheduled interval.

TABLE X
DISTRIBUTION OF REGULARITY EACH STATION

Station	% of Pass		
	Workday	Weekend	Average
Bus Stop (Ipoh to Lumut Direction)			
TmMj	50	50	50
BtKa	50	58.3	54.2
AyTw	66.7	41.7	54.2
Stwn	50	41.7	45.8
MjBs	25	16.7	20.8
Bus Stop (Lumut to Ipoh Direction)			
MjBs	30	22.2	26.3
Stwn	41.7	25	33.3
AyTw	0	8.3	4.2
BtKa	0	8.3	4.2
TmMj	0	8.3	4.2
Bus Stop (Average)			
TmMj	25	29.2	27.1
BtKa	25	33.3	29.2
AyTw	33.3	25	29.2
Stwn	45.8	33.3	39.6
MjBs	27.3	19	23.3
Main Bus Station and Bus Stop			
Iph Bus sta	16.7	41.7	29.2
Lmt Bus sta	25	16.7	20.8
Bus stop	31.3	28	29.7

TABLE XI
MONTHLY DISTRIBUTION OF REGULARITY IN 2007

Regularity (%)	± 5 minute	± 10 minute	± 15 minute
Jan	0	4.2	47
Feb	20.8	58.3	83.3
Mar	33.3	62.5	62.5
Apr	58.3	66.7	79.2
May	25	58.3	87.5
Jun	20.8	51.1	55.3
Jul	54.2	66.7	83.3
Aug	54.2	66.7	83.3
Sep	4.2	16.7	33.3
Oct	47.7	65.2	78
Nov	13.6	47.7	65.2
Dec	12.5	37.5	66.7

TABLE XII
EARLY, ON-TIME PERFORMANCE, LATE AND REGULARITY

Station	Early < -5 min	Early -5-0 min	On-Time 0-5	Late >5	Regularity ± 5 minute
Iph Bus sta	0	4	25	71	29.2
Lmt Bus sta	0	13	8	79	20.8
Bus Stop	2	17	11	70	29.7

V. CONCLUSION

The on-time performance and service regularity of stage bus in mixed traffic can be derived by using the data collected from on-board survey. The results show clearly that stage bus operated in mixed traffic can be categorized as low on-time performance and low service regularity. These two approaches could measure the reliability of bus service with many other related variables and consecutively useful for operator/investor, regulator and customers/users for consideration in enhancing the efficiency and effectiveness of bus service delivery and operations.

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