A Study of Bus Bunching Service using Single-server and Multi-server Queuing System

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Introduction

Bus bunching system are very popular in public transport. The common bus bunching problem, which is the time delay, is defined as the scheduled of the bus which are not irregular that will affect the number of passengers boarding the bus. This study aims to find the solution of the problem to improve the bus bunching system by using single-server model and multi-server model. These two models are very effective in queuing system because they can ensure the maximum utilization of the bus bunching. Passenger that will board the bus at each of the bus stop are inconstant because of the community people and time. The bus bunching schedule should be more emphasize during peak hour especially on weekdays. Data is taken from the study in Kota Surakarta in Rahmawati (2009).

Methodology

Generally, this study focuses on analyzing bus bunching using single-server queuing system and multi-server queuing system. In single-server model, the number of servers will always be equal to one, (c=1). When the server are more than one, it is considered as multi-server model. Table 1 shows the formulation of the both models. The program Visual Basic for Applications (VBA) which is built-in programming language in the Microsoft Office Excel application were used in this study.

Table 1 Formulation of single-server and multi-server model

	Single-Server Model	Multi-Server Model
Utilization of each server (ϱ)	$\varrho = \frac{\lambda}{\mu}$	$\varrho = \frac{\lambda}{c\mu}$
Probability that all servers are idle (ϱ_0)	$P_0 = 1 - \frac{\lambda}{\mu}$	$P_0 = \frac{1}{\left[\left(\sum_{n=0}^{c-1} \frac{1}{n!}\left(\frac{\lambda}{\mu}\right)^n\right) + \frac{1}{c!}\left(\frac{\lambda}{\mu}\right)^c\left(\frac{1}{1-\varrho}\right)\right]}$
Average number of customers in queue (L_q)	$L_q = \frac{\lambda^2}{\mu(\mu-\lambda)}$	$L_q = \frac{\varrho\left(\frac{\lambda}{\mu}\right)^c P_0}{c!(1-\varrho)^2}$
Average number of customers in system (L_s)	$L_s = \frac{\lambda}{\mu-\lambda}$	$L_s = L_q + \frac{\lambda}{\mu}$
Average time a customer spends in the queue (W_q)	$W_q = \frac{\lambda}{\mu(\mu-\lambda)}$	$W_q = \frac{L_q}{\lambda}$
Average time a customer spends in the system (W_s)	$W_s = \frac{1}{\mu-\lambda}$	$W_s = \frac{L_s}{\lambda}$

Results and discussion

The data are obtained from Rahmawati (2009), are the number of passengers at each of the bus stop in Kota Surakarta. There are 45 bus stops along the route in Kota Surakarta that are recorded in the study. The data were taken for every day from Monday to Sunday starting on 6.00 am until 6.00 pm which is total up to 12 hours. Table 2 shows the values of λ, μ and of the 45 bus stops along the route.

The lower value of utilization , the more stabilization of the data. For LP bus stop, the utilization value is 0.2444 and it is the lowest value compared to other bus stop. It shows that, LP bus stop is the most stable and effective bus stop because LP bus stop has the stable number of passengers that boarding the bus.

Besides that, other parameter such as P0, Lq, Ls, Wq and Ws were calculated and the value of these parameters should be positive. From 45 bus stops, 28 bus stops get all the positive value if the single-server model was applied. So, it means that the bus stop is enough with only one bus to serve the passengers. For other 17 bus stops, the value of parameters P0, Lq, Ls, Wq and Ws are negative. Hence, the multi-server queueing model were applied for the 17 bus stops until all the parameters become a positive value. Which means that, the number of servers is added one by one until all the parameters become positive values. 16 bus stops suitable for two servers while only one bus stop which is Panggung that suitable for three servers.

Table 2 Value of λ, μ and ρ

Bus stop	λ	μ	ρ	Bus stop	λ	μ	ρ
Colomadu	4.4583	5.0000	0.8917	Pos Solo	0.7917	1.1667	0.6786
Giwangan	4.3333	4.6667	0.9286	Gladag	5.9583	7.3333	0.8125
Gajahan	2.3750	4.8750	0.4872	Kauman	3.3750	2.6667	1.2656
Tg. Adipura	0.7917	1.3750	0.5758	LP	1.8333	7.5000	0.2444
Solo Pos	0.7083	0.5833	1.2143	Nonongan	2.3333	2.6667	0.875
Universitas Sahid	1.0417	0.8333	1.25	Singosaren	0.9167	1.0000	0.9167
Fajar Indah	1.7917	1.7500	1.0238	Wisma Batari	1.7083	1.7500	0.9762
Pabrik Menara	1.0000	0.5833	1.7143	Luwes	0.5833	1.2917	0.4516
Pabrik DjiToe	0.6250	0.4583	1.3636	Gramedia	0.7083	1.3750	0.5152
Regina Pacis Ursulin	1.2083	1.0000	1.2083	Pengadilan Negeri	0.1667	0.2083	0.8
SMK5	2.4167	2.7917	0.8657	THR Sriwedari	0.4583	0.6250	.0.7333
SMK4	3.0833	3.5000	0.881	Man	0.8750	1.7500	0.5
Persimpangan Manahan	6.2500	4.5833	1.3636	SGM	5.3333	6.5000	0.8205
SMKN6	3.9583	2.6250	1.5079	Gendengan	5.3750	6.0833	0.8836
SMPN12	1.3333	1.3750	0.9697	RS Kasih Ibu	2.7083	3.8333	0.7065
Pasar Ngemplak	2.9583	3.7500	0.7889	Brengosan	1.3333	1.2500	1.0667
Panggung	24.0833	11.2500	2.1407	Purwosari	4.5000	4.9583	0.9076
Pasar Ledoksari	2.1667	2.4583	0.8814	SMA Batik	5.0000	4.4583	1.1215
Mesen	0.6250	0.6250	1	UNS PGSD Kleco	8.1667	13.4583	0.6068
SMPN26	2.9583	2.5000	1.1833	Solo Square	1.5000	1.5000	1
Asia Baru	1.5000	2.0417	0.7347	Persimpangan Kerten	0.7083	0.6250	1.1333
Pasar Gede	5.6250	7.4167	0.7584	RS Paru-paru	0.5000	0.6250	0.8
Balaikota	4.3333	3.2500	1.3333				

The highest average time of passengers spends in the queue (Wq) is at Pabrik Menara bus stops, which is 4.7496 while the lowest is at Panggung bus stop, which is 0.0586. Same goes to the average time passengers spend in the system(Ws), where the highest is also at Pabrik Menara bus stops, which is 6.4640 and the lowest time is at Panggung bus stop which is 0.1475.

Conclusion

The problems of bus delay and low rate of service usually occur in bus transportation services, these lead to an increase in passengers' waiting time, hence increasing the number of waiting passengers at the next stop. The single-server model formulas was applied at 45 the bus stop to determine the utilization of each server ( ). From the value of at each of the bus stop, the efficiency of each bus stop were identified.

The increase of the server will increase the efficiency of the bus bunching system. However, the increase of the server will automatically increase the cost to provide more buses including their maintenance services. For this study, 62.22%, 35.56% and 2.22% of the bus stops are suitable for one server, two servers, and three servers, respectively. Bus bunching service are operated from the first bus stop, until the last 45th bus stop. If we employ multi-server queueing model for the bus bunching service at Kota Surakarta, it will start at Colomadu and ended at RS Paru-paru. So, it is such a waste at the 62.22% of the bus stops because more buses are provided for the less passengers. Therefore, it is recommended to use only single-server queueing system. But, at 37.78% of the bus stops, some of the passengers must wait for bus a little longer.

References

Rahmawati, M. (2009). Penentuan Jumlah Dan Lokasi Halte Rute I Bus Rapid Transit (Brt) Di Surakarta Dengan Model Set Covering Problem Mardiana Rahmawati Nim I 0303034 Jurusan Teknik Industri Fakultas Teknik. *Skirpsi*, 1–162.