Public Transport Service Provisions and Policy Implications for Columbarium Trips

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ABSTRACT
Grave-sweeping is one of the popular special events in Asian cities, especially in Chinese societies, in which families express filial piety to their ancestors during two traditional grave-sweeping festivals in a year. The extraordinary high travel demand is often attracted to columbaria within a relative short period around the festivals, and induces severe impacts to the local traffic. It is challenging for the government and private operators to formulate a public transport service setting to satisfactorily cater all the visitors' travel demand. This paper aims to propose an optimization framework to identify the optimal provisions of public transport services for columbarium trips to achieve consumer surplus or profit maximization. Numerical studies are carried out using the travel demand data collected from a selected columbarium, to examine the effects of different public transport service settings to the policy objectives in various cases. The model results show that the current situation is neither consumer surplus nor profit optimum. Improvement schemes are suggested in relation to allow various fares during different visit periods and provide multiple public transport feeder services to serve the visitors during the high travel demand period.

Key words: Columbarium trips, Special events, Consumer surplus and profit maximization models, Public transport service provision, Public transport policy

1. INTRODUCTION
The impacts to local traffic induced by special events (e.g., exhibitions, concerts, football matches, and carnivals) are usually more severe than those on normal days, because special events attract extraordinarily high travel demand within a relative short period. It is challenging for the government and private operators to formulate a public transport service setting to satisfactorily cater the travel demand of all participants.

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Grave-sweeping is one of the popular special events in Asian cities, especially in Chinese societies (e.g., Hong Kong), in which families express filial piety to their ancestors during two traditional grave-sweeping festivals (i.e., Ching Ming Festival in early-April and Chung Yeung Festival in mid-October) every year. In most cases, the remains of the ancestors are either buried in graves of cemeteries or entombed in niches of columbaria. Because graves occupy more space and land supply is severely limited [1], there was no more large-scaled cemetery developed since 1976 in Hong Kong. In the past forty years, the government has developed numerous columbaria at many locations, in which majority of them built as multi-storey buildings with high niche density. Although the demand for entombing ancestors could be addressed in this way, columbaria cause more severe impacts to the local traffic than cemeteries because of their high travel demands. Many visitors go to columbaria for grave-sweeping on or around the festival dates, and the neighbouring weekends (including Saturday and Sunday) and public holidays. The number of visitors often exceeds the handling capacities of the public transport facilities and services provided, it causes traffic congestion. According to the headcount survey conducted by Szeto et al. [2], the number of visitors on a peak date of grave-sweeping festival traveling towards a selected columbarium (i.e., Yuen Yuen Institute) was 1,078 in an hour, which was about 20 times more than that on a normal day. Therefore, an appropriate temporary public transport arrangements providing adequate handling capacity would be more favourable than providing regular services at all time to cater the travel demands.

Considering that most of the columbaria in Hong Kong are located at remote areas (sometimes located at hillsides), public transport feeder services (usually private operated) are always provided for transporting visitors to and from nearby railway stations or public transport interchanges to serve the high travel demand to these sites from two weeks before until two weeks after the festivals. However, the temporary public transport arrangements are designed without any empirical support while ignoring the travel behaviour of the visitors, and thus both the appropriateness and effectiveness are questionable.

Numerous researches have been conducted for the temporary traffic arrangements of special events internationally and have been focused on the aspects of travel demand modelling [3, 4], predicting mode choices of participants towards the event venues [5, 6], modelling pedestrian movements inside and around the event venues [7] and recommending temporary traffic management measures [8, 9]. However, limited researches have considered grave-sweeping or similar type of special events, except Szeto et al. [2, 10] modelling the travel demand and studying the arrival time choice behaviour of the visitors. Unlike the other special events like concerts or football matches having a fixed event date and time, the visitors towards columbaria could choose their preferred date and time to visit around the festival dates. Therefore, the suggestions from the previous researches for other special events cannot be applied directly. A comprehensive study for establishing temporary public transport arrangements for grave-sweeping is, therefore, worth to be carried out. This is related to the area of public transport network design.

Public transport network design received extensive research interest for its practical importance in the past decades, and comprehensive reviews on this research area have been conducted [11–13]. Most of the existing researches have focused determining and optimizing the public transport service route [14–16], frequency [17–19], fare [20], schedules of vehicle [21] and crew [22] and a combination of the above [23–26] based on an assumption of static travel demand while ignoring the travel demand variation over time. For the travel characteristics of columbarium trips, there is a high variation in travel demand between peak flows during grave-sweeping festivals and off-peak flows on normal days. Assuming a uniform travel demand pattern as the same to the previous research for designing the public transport arrangements can lead to unsatisfactory services to the passengers such as overcrowding at public transport interchanges, long waiting time there, and in-vehicle congestion. It is essential to take the variation into account when designing the arrangement.

During the design stage, the choice of combination of public transport modes (e.g., bus or mini-bus) to provide the services on each day of a year is a critical consideration because each mode has its own characteristics, such as operating speed and capacity. When the travel demand is low, it makes sense to choice mini-bus because the annual operating cost is lower, its speed is faster and seat availability is guaranteed. When the travel demand is high on some days, bus is a more reasonable choice, as buses have a higher capacity. However, the total capacity from buses may not be enough to cater for the high demand, leading to allowing more than one mode to provide the services. To sum up, what the best combination of public transport modes provided on each day of a year is a critical design consideration.

Who provide the services is also an important design consideration. If the services are provided by a private operator, profitability will be the sole concern for the public transport services. Satisfactory services will only be provided during the profitable period (i.e., during the grave-sweeping festivals when the travel demands are high) and limited and poor services will be provided on normal days in order to maximize the overall profit. Moreover, fare may be unreasonably high. If the government takes over the responsibility to provide services from the perspective of society, the services will likely be more frequent with a lower travel fare but the operational cost may be much higher than that provided by a private operator. This raises policy implications regarding whether and how to privatize the services.

This paper aims to formulate an optimization framework to identify optimal provisions of public transport services for columbarium trips to achieve either consumer surplus or profit optimization. Numerical studies are carried out using the travel demand data collected from a selected columbarium to examine the effects of different public transport service settings to the policy objectives in various cases. Based on the model results, insights and suggestions of public transport policy measures for achieving desirable feeder services to the visitors for grave-sweeping during different visit periods with various travel demand levels are provided.

The remainder of this paper proceeds as follows. Section 2 provides the problem formulation and the details of cases with different service settings. Section 3 introduces the data collected from a selected columbarium and used in this study. Section 4 demonstrates the effects of adjusting the public transport service settings to consumer surplus and profit over the modelling horizon, discusses the potential public transport policy implications, and conducts sensitivity tests to identify the uncertainty of operating the services. Finally, Section 5 concludes the paper.

2. PROBLEM FORMULATION

2.1. Notations

The following notations are used throughout this paper:

t	Index of visit period;
T	Set of visit periods;
n	Index of public transport mode;
N	Set of public transport modes;
C_n^t	Total travel cost of public transport mode n during visit period t (HK$);
P_n	Fixed fare of public transport mode n for all visit periods (HK$);
P_n^t	Adjustable fare of public transport mode n during visit period t (HK$);
P_{max}	Maximum fare of public transport modes (HK$);
W_n^t	Waiting time of public transport mode n during visit period t (minutes);
I_n	In-vehicle travel time of public transport mode n (minutes);
D_n^t	Overflow delay of public transport mode n during visit period t (minutes);
F_n^t	Frequency of public transport mode n during visit period t (vehicles/hour);
F_{max}	Maximum frequency of public transport modes (vehicles/hour);
C_w	Total cost of walking mode (HK$);
K	Walking time (minutes);
λ	Value of time (HK$/minute);
S	Annual consumer surplus (HK$/year);
Z	Annual profit (HK$/year);
R	Total service hour per year of all public transport modes (hours/year);
ω^t	Weighting factor of visit period t, which is set to be equal to the number of days in the period considered;
θ	Parameter of logit model (HK^{-1});
M^t	Travel demand from the public transport interchange to a columbarium during visit period t (visitors/hour);
H_n^t	Passenger flow of public transport mode n during visit period t (passengers);
O_n^t	Operational cost of public transport mode n during visit period t (HK$);
Q_n^t	Total capacity of public transport mode n during visit period t (passengers);
V_n	Vehicle capacity of public transport mode n (passengers/vehicle);
α_n	Fuel cost per unit distance of public transport mode n (HK$/kilometre);
L_n	Travel distance of public transport mode n (kilometres);
β_n	Salary of drivers per unit time of public transport mode n (HK$/minute); and
μ	Scaling factor of in-vehicle travel time to all public transport modes.

2.2. Assumptions

Three main assumptions are made in this study: 1) the visitors select the transport mode with the lowest perceived travel cost and their mode choice can be modelled by logit model; 2) the travel demand between each origin-destination pair is known, symmetric, and fixed, which is reasonable for strategic planning when the day-to-day variation is small and negligible; and 3) the in-vehicle travel time for one direction is the same as that for the opposite direction.

2.3. Transport Modes and Their Costs

In this study, two categories of transport modes are considered by the visitors traveling back and forth columbaria for grave-sweeping: 1) either one or both of the public transport modes, where the first one (equivalent to bus in this study) accommodates more passengers with a lower travel speed, and the latter one (equivalent to mini-bus in this study) has a smaller vehicle capacity but travels faster under normal situations, and 2) walking mode. Therefore, each visitor indeed has three choices at most. The visitors are assumed to make their mode choices based on perceived travel cost minimization. The cost components associated with the public transport modes and walking mode are defined in the following Equations (1)–(3):

$$C_n^t = P_n^t + \lambda\left(W_n^t + I_n + D_n^t\right), \forall n \in N, t \in T \tag{1}$$

$$W_n^t = \frac{30}{F_n^t}, \forall n \in N, t \in T, \text{ and} \tag{2}$$

$$C_w = \lambda K. \tag{3}$$

Equation (1) states that for the two public transport modes, the travel cost of each passenger equals the corresponding fare plus the sum of the expected waiting time, in-vehicle travel time, and overload delay multiplied by the value of time. Equation (2) states that the expected waiting time is set to be equal to half of the headway, in which the headway equals the reciprocal of frequency. The number in the numerator is a conversion factor. Equation (3) states that for the walking mode, the total travel cost of a traveller simply equals to the product of the walking time and the value of time.

2.4. Optimization Framework

We consider two candidate operators to run the public transport feeder services transporting the visitors between the columbarium and the public transport interchange of the nearest railway station: 1) the government, and 2) a private operator. From the government's point of view, the consumer surplus over the modelling horizon should be maximized subject to cost recovery constraints. However, from the private operator's point of view, its profit over the modelling horizon should be maximized. The objective function in the resultant model is, therefore, different depending on the perspective of the operator. In the following, the proposed optimization framework is presented.

$$\max S = R \cdot 2\sum_{t \in T}\left\{\omega^t \cdot \frac{1}{\theta}\ln\left[\exp\left(-\theta C_w\right) + \sum_{n \in N}\exp\left(-\theta C_n^t\right)\right] \cdot M^t\right\}, \text{ and} \tag{4}$$

$$\max Z = R \cdot 2\sum_{t \in T}\left[\omega^t \cdot \sum_{n \in N}\left(P_n^t H_n^t - O_n^t\right)\right], \tag{5}$$

subject to:

$$H_n^t \le Q_n^t, \forall n \in N, t \in T, \tag{6}$$

$$O_n^t \le P_n^t H_n^t, \forall n \in N, t \in T, \tag{7}$$

$$0 < F_n^t \le F_{\max}, \forall n \in N, t \in T, \tag{8}$$

$$0 \le P_n^t \le P_{\max}, \forall n \in N, t \in T, \tag{9}$$

$$H_n^t = \frac{\exp\left(-\theta C_n^t\right)}{\exp\left(-\theta C_w\right) + \sum_{n \in N}\exp\left(-\theta C_n^t\right)} \cdot M^t, \forall n \in N, t \in T, \tag{10}$$

$$Q_n^t = V_n F_n^t, \forall n \in N, t \in T, \text{ and} \tag{11}$$

$$O_n^t = \left(\alpha_n L_n + \beta_n I_n\right) F_n^t, \forall n \in N, t \in T, \tag{12}$$

Objective (4) is to maximize the annual consumer surplus minus a constant term. Including the constant term in the objective function does not alter optimal solutions of the model. Hence, objective (4) is the one that can reflect the government's objective. For simplicity, the objective function value is still referred to as annual consumer surplus. Objective (5) is the one concerned by the private operator. Constraint (6) depicts the capacity constraint for each public transport mode, stating that the capacity of each mode must be higher than or equal to the corresponding passenger flow in each visit period considered. Constraint (7) describes the cost recovery constraint of the public transport mode, requiring that the revenue collected by each mode in each visit period is at least equal to the corresponding operating cost. Constraints (8) and (9) define the domain of the decision variables, stating that the frequency and fare of each public transport mode is bounded by zero and their corresponding upper bound.

Passenger flow of the public transport mode can be calculated by Equation (10), according to the logit modelling principle [27]. The total capacity of each public transport mode is calculated by multiplying the capacity of a single vehicle with its frequency, as described in Equation (11). The operational cost of each public transport mode is proportional to the frequency, taking into account the travel distance, fuel cost, salary of drivers and in-vehicle travel time, as in Equation (12).

2.5. Settings of Public Transport Services

We aim to investigate the effects of two settings of public transport services to the optimal consumer surplus and profit: 1) adjustable fare for different visit periods; and 2) multiple public transport feeder service provision. To clearly illustrate the effects, this paper considers the following four cases.

Case 1 Fixed fares at all time with single public transport feeder service provision

This case reflects the current practice when the objective is to maximize the total profit over the modelling horizon. Only one out of two public transport feeder services is provided (i.e., $|N| = 1$). and its fare cannot be changed for different visit periods restricted by the public transport policy. It charges in a uniform rate for the whole year (i.e., $P_n^t = P_n$).

Case 2: Fixed fares at all time with two public transport feeder service provisions

Compare to Case 1 above, we allow two public transport feeder services to cater the travel demand of visitors for grave-sweeping simultaneously (i.e., $|N| = 2$). The travel fares of different public transport modes remain fixed and independent to different visit periods.

Case 3: Adjustable fares for different visit periods with single public transport feeder service provision

Providing public transport feeder service with a fixed fare cannot guarantee that either consumer surplus or profit can be maximized. In this case, we let the same transport mode can charge differently during various visit periods. Thus, the optimal solutions for different visit periods are independent. Only one public transport feeder service is offered.

Case 4: Adjustable fares for different visit periods with two public transport feeder service provisions

We relax both the restrictions stated above to allow fares to vary over visit periods and two public transport feeder services to serve the visitors traveling back and forth the columbarium and the public transport interchange of the nearest railway station.

3. DATA

The data introduced in this section was acquired and used during the previous study of the authors about the trip attraction, trip distribution and modal split of columbarium trips [2]. In this paper, the columbarium of Yuen Yuen Institute is selected as the target site to investigate the model performance and to suggest public transport policy measures. Yuen Yuen Institute is one of the popular large-scale columbaria in Hong Kong with 43,077 occupied niches, attracted about 7,500 visitors in a day during Ching Ming Festival. The visitors can choose either walking for 4 kilometres (which takes about 45 minutes) or traveling by a mini-bus (which takes less than 15 minutes) provided by a private operator to the columbarium from the nearest railway station. Currently, 16 seated mini-bus is the only public transport mode in service whereas double-decked bus is not available for the visitors (and will be studied in the result section to investigate whether double-decked bus is more favourable to serve the high travel demand). The fare for this shuttle service is fixed at HK$4.5 for all time and its frequency is varied subject to the travel demand.

The value of time (λ) equals to HK$0.5/minute [28], which is the latest value available currently. Assuming that the logit model parameter (θ) is 1 HK$$^{-1}$, and the maximum fare ($P_{max}$) and frequency ($F_{max}$) for both bus and mini-bus are 60 vehicles/hour and HK$60, respectively. The characteristics of the three transport modes are shown in Table 1. It is worth emphasizing that the average travel speed of mini-bus would always be faster than that of bus under the normal situations as observed in Hong Kong, since mini-bus is lighter and smaller, which makes it easier for manoeuvring especially for the hillside roads towards the columbarium. However, if the access road is heavily congested, the advantage on the travel speed of mini-bus will be cancelled out. To capture the uncertainty of travel speed, we suggest imposing a scaling factor (μ) of the in-vehicle travel time to bus over mini-bus in this study.

The travel distance between the columbarium and the public transport interchange (L_n) was about 4 kilometres. The walking time to Yuen Yuen Institute from the nearest railway station was about 45 minutes. The in-vehicle travel time of the existing feeder services of mini-bus was about 12 minutes. Since mini-bus was the unique public transport mode recently provided on site for the visitors, only its in-vehicle travel time could be obtained. A scaling factor was then introduced here to estimate the in-vehicle travel time of bus. Bus could accommodate 136 passengers in one trip, and mini-bus could only accommodate 16 passengers. The fuel cost of mini-bus was significantly lower than that of bus (mini-buses and buses consumed about 15.4 and

Table 1. Characteristics of the three transport modes

	Transport Modes		
Parameters	Bus	Mini-bus	Walking
Walking time (minutes)	–	–	47.60
In-vehicle travel time (minutes)	11.72	11.72	–
Capacity (passengers/vehicle)	136	16	–
Fuel cost (HK$/trip)	20.81	6.82	–
Salary cost (HK$/trip)	12.70 μ	12.70	–

47.0 litres of diesel, respectively, per 100 kilometres travelled and the unit cost of diesel was about HK$11.07 per litre) [29]. Given that the hourly salary of a bus driver was about HK$65 [30] and assumed to be the same to a mini-bus driver, the salary cost of bus per trip equalled to HK$12.70 μ, which was the product of salary of drivers per unit time and the in-vehicle travel time. Similarly, the salary cost of mini-bus was HK$12.70 per trip.

The weighting factors associated with different visit periods and their travel demands are tabulated in Table 2. There were 6 and 8 days (Saturdays, Sundays and public holidays) from two weeks before until two weeks after the festival dates of Ching Ming Festival and Chung Yeung Festival, respectively, which identified as peak days for the visitors going the columbarium for grave-sweeping, while the other days were considered to be normal days. The weighting factor (ω^t) was calculated by dividing the number of the specific days by 365 days in a year. A headcount survey was conducted to record the number of visitors traveling towards Yuen Yuen Institute on the peak days of Ching Ming Festival, and the neighbouring weekdays (considered to be normal days). The average number of visitors entering the site was 1,078 visitors/hour during the operation period between 9am to 4pm (7 hours), and the trips made on weekdays comprised only 3% of the peak value. In addition, according to the results of the questionnaire survey, about half of the respondents would re-visit the columbarium during Chung Yeung Festival. Hence, the travel demand in Chung Yeung Festival was estimated as 539 visitors/hour. It is worth mentioning that the number of visitors entering the columbarium should be equal to the number of visitors leaving, since they have to leave the columbarium after their visits. Most likely they will return to the public transport interchange of the nearest railway station, where they come from.

It is noticed that the visitors were highly concentrated on a few days towards the columbarium for grave-sweeping during Ching Ming Festival, and the demand is lower on or around Chung Yeung Festival and reach the minimum on the normal days. To deal with the various levels of travel demand, the proposed modelling framework is reduced to three independent sub-models: high demand model (i.e., due to Ching Ming Festival), medium demand model (i.e., due to Chung Yeung Festival) and low demand model (i.e., for normal days) to seek the optimal public transport arrangement for each visit period under the two objectives and four cases mentioned before.

Table 2. Weighting factors and travel demands associated with different visit periods

	Visit Periods for Grave-sweeping		
Parameters	Ching Ming Festival	Chung Yeung Festival	Normal Days
Number of specific days	6	8	351
Weighting factor (ω^t)	0.016	0.022	0.962
Travel demand (visitors/hour)	1,078	539	32

The unit objective values of consumer surplus and profit per trip per hour equal the sum of the individual values of different visit periods multiplied by the associated weighting factors. The answers are further multiplied by two for the return trip and the annual operation hours of 2,555 (i.e., 365 days x 7 hours) as in Objectives (4) and (5) for the annual values.

4. RESULTS AND DISCUSSIONS

4.1. Results for Case 1

According to the travel demand distribution among different visit periods, the mode choice for the public transport feeder services should be monotonic. Therefore, four mode choice combinations are considered in this study: 1) "bbb" (i.e., provide bus service for all time periods), 2) "bbm" (i.e., provide bus service for Ching Ming Festival and Chung Yeung Festival, while providing mini-bus for the normal days), 3) "bmm" (i.e., provide bus service for Ching Ming Festival only, while providing mini-bus for Chung Yeung Festival and the normal days), and 4) "mmm" (i.e., provide mini-bus services for all time periods). To sum up, b and m denote bus and mini-bus services, respectively. The first letter represents the feeder service due to Ching Ming Festival, the second letter for Chung Yeung Festival, and the last one for the normal days.

The models were solved using Risk Solver Platform 11.5.2.0. The optimal annual consumer surpluses and profits (over the modelling horizon) obtained using the aforementioned mode choices under different values of μ are plotted in Figures 1 and 2, respectively, for Case 1 which reflects the current situation when the objective is to maximize annual profit. As shown in the figures, the number of time periods using bus as the single public transport feeder service is decreasing along the direction of x axis. For consumer surplus maximization as shown in Figure 1, the optimal mode choice combination is "bbm" when $\mu=1$ (with an annual consumer surplus of –HK$3.01 million), and the optimal combination is "bmm" when $\mu=1.2$ (with an annual consumer surplus of –HK$3.19 million) and $\mu=1.5$ (with an annual consumer surplus of –HK$3.35 million).

In Figure 2 for annual profit maximization, the mode choice combinations optimized at "bbm" when $\mu=1$ (with an annual profit of HK$3.27 million), at "bmm" when $\mu=1.2$ (with an annual profit of HK$3.11 million), and at "mmm" when $\mu=1.5$ (with an annual profit of HK$3.02 million).

To have a joint discussion of Figures 1 and 2, it is noticed that the optimal objective values for both the cases decreases as the value of μ increases. As the value of μ will not affect both the passenger's total travel cost and the operator's operational cost of the services provided by mini-bus, the three lines will end up at the same point (i.e., when "mmm" combination is used). It can be observed that buses are recommended for Ching Ming Festival in most cases when the travel demand is high, and mini-buses are particularly suitable for the normal days with limited travel demand to the columbarium for grave-sweeping. The results provide us an important message that the current public transport service arrangement of providing mini-buses at all time with a fixed fare is not the optimal solutions for all cases while considering consumer surplus. It is only

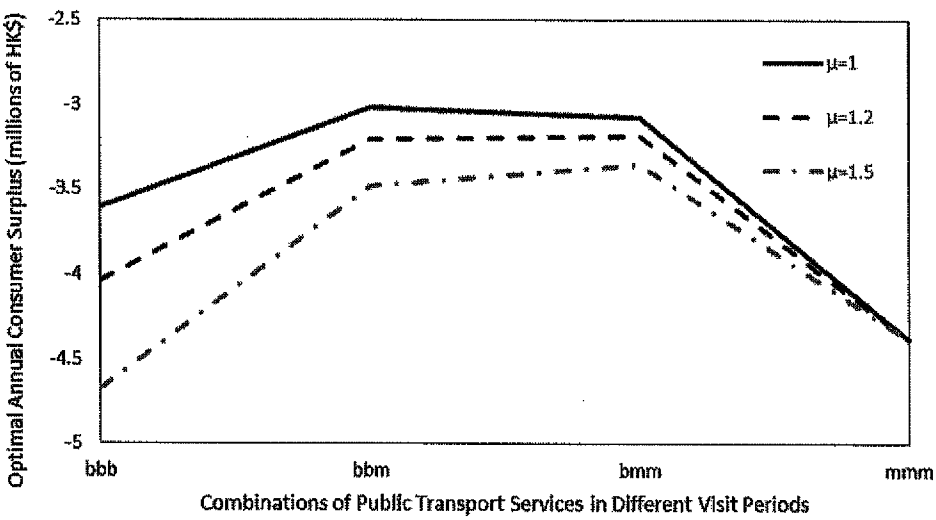

Figure 1. Optimal annual consumer surplus under different public transport service provisions and different scaling factors of in-vehicle travel time

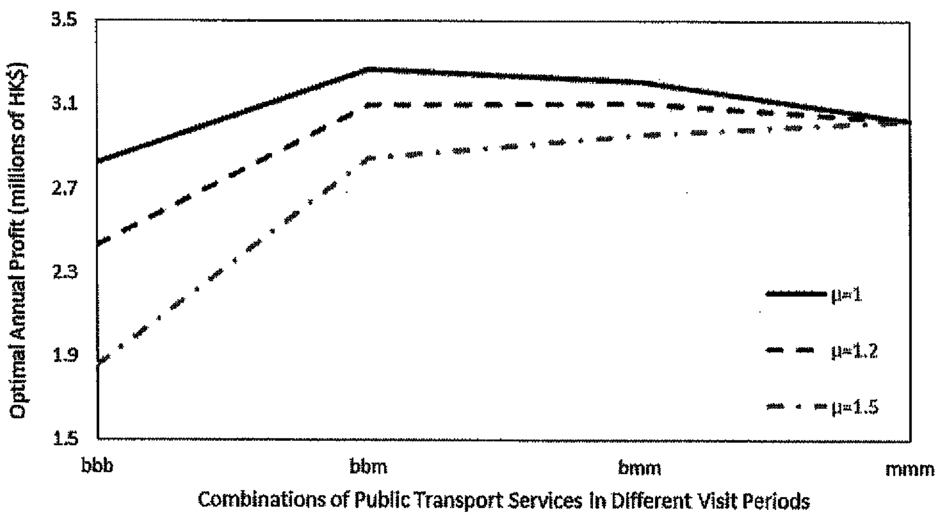

Figure 2. Optimal annual profit obtained under different public transport service provisions and different scaling factors of in-vehicle travel time

optimum for the profit maximization in the extreme case when the in-vehicle travel time of bus is significantly longer than that of min-bus (i.e., μ=1.5). Therefore, the current public transport arrangement cannot guarantee that the objective values will always be maximized in different cases. Improvement schemes should be considered carefully to investigate whether better solutions can be achieved.

4.2. Results for Potential Improvement Schemes

Table 3 tabulates the optimal solutions of all cases with different objectives and scaling factors, which provide the insights of the public transport policy implications to achieve better objective values.

Although optimal solutions using single public transport mode would be more desirable in practice because of its simplicity (as in Case 1), using multiple public transport modes simultaneously could improve the objective values because of the larger feasible region. By allowing two public transport modes to be used simultaneously, the optimal solutions are shown in Case 2. It is noted that the objective values are all the same when $\mu=1$, which implies that providing multiple public transport feeder services make no different if the fares are fixed at all time. When μ increases to 1.5, which means that the in-vehicle travel time of bus is significantly longer than that of mini-bus, the consumer surplus and profit will be improved by 5.57% and 2.27% respectively. However, the improvements are limited and not guaranteed for all cases. Additional improvement schemes should be considered.

Table 3 further presents the results of the cases with adjustable fares of the public transport feeder services (for single public transport mode in Case 3 and two public transport modes in Case 4). As comparison between Cases 1 and 3, the optimal mode choices is changed to "bmm" while considering consumer surplus when $\mu=1$, and changed to "mmm" while considering profit when $\mu=1.2$. It demonstrates that mini-bus becomes more favourable as the public transport mode (if only single mode can be provided), when fare is adjustable.

The findings show that the optimal objective values of Case 4 will always be higher than or equal to those of Case 3. The improvements are based on allowing multiple public transport feeder services during Ching Ming Festival when it has a high travel demand (no improvement is contributed from the medium and low travel demand sub-models). It is mainly because the upper bound of the frequency of the public transport service is reached and the travel demand is too high such that the maximum capacity of one single mode is insufficient to serve the visitors' travel demand.

Table 3. Estimated consumer surpluses and profits for different cases

Objectives	Scaling Factors	Optimal Objective Values[a] (millions of HK$) Case 1	Case 2	Case 3	Case 4
Maximizing consumer surplus	$\mu=1$	–3.01 (bbm)	–3.01 (bbm)	–3.00 (bmm)	–2.97 (xmm)
	$\mu=1.2$	–3.19 (bmm)	–3.11 (xxm)	–3.11 (bmm)	–3.01 (xmm)
	$\mu=1.5$	–3.35 (bmm)	–3.17 (xxm)	–3.27 (bmm)	–3.04 (xmm)
Maximizing profit	$\mu=1$	3.27 (bbm)	3.27 (bbm)	3.29 (bbm)	3.31 (xbm)
	$\mu=1.2$	3.11 (bmm)	3.11 (xmm)	3.28 (mmm)	3.28 (xmm)
	$\mu=1.5$	3.02 (mmm)	3.09 (xmm)	3.28 (mmm)	3.28 (mmm)

Note: [a]The optimal mode choice for different visit periods is provided in the blanket, where x denotes mixed transport mode while providing buses and mini-buses for feeder services simultaneously.

To sum up, the objective values are gradually improved from Cases 1 to 4, and Case 4, which allows adjustable fare for different visit periods and provides two public transport feeder services, gives the best objective values. Compared with the current situation (Case 1), consumer surplus and profit will be improved by 9.27% and 7.67%, respectively.

The findings provide some public transport policy implications on improving the current situation by 1) allowing adjustable fare for different visit periods, and 2) providing multiple public transport modes during Ching Ming Festival when the travel demand is high, especially for the cases of considering consumer surplus and the travel speed of mini-bus is significantly higher than that of bus, or for the cases of considering profit and the access road is congested (leading to a similar in-vehicle travel time of bus to mini-bus).

Table 4 shows that public transport arrangement of the optimal solution (Case 4) on the frequency and fare for different visit periods. It is noticed that when considering consumer surplus maximization, the provided frequencies are higher than those for profit maximization in most cases, while having a lower fare in general. Mixed transport mode (which is equivalent to provide additional bus service on top of the existing arrangement) is usually suggested during Ching Ming Festival, except $\mu=1.5$ when and considering profit maximization.

This paper provides a valuable reference for the policy makers to judge whether the public transports should be offered by the government or a private operator. Generally speaking, consumer surplus is the major concern for the government. If the government decides to invite a private operator to manage the public transport feeder service, profit will become the major concern, which may conflict the objective of the government. From the model results, we notice that there exists a direct conflict between consumer surplus and profit maximizations, which cannot be achieved at the same time as reflected by the service details in Table 4. Frequency in consumer surplus maximization models tend to be as high as possible, which leads to a high operational cost. On the other hand, fares in profit maximization models could be unreasonably high for the

Table 4. Public transport arrangements of the optimal solution in Case 4

Objectives	Scaling Factors	Service Details for Different Visit Periods[a] Frequency (vehicles/hour)	Fare (HK$)
Maximizing consumer surplus	$\mu=1$	b:15.9, m:27.3 (m:33.7) [m:5.0]	b:0.7, m:1.5 (m:1.2) [m:3.0]
	$\mu=1.2$	b:5.7, m:60.0 (m:33.7) [m:5.0]	b:0, m:1.4 (m:1.2) [m:3.0]
	$\mu=1.5$	b:12.8, m:60.0 (m:33.7) [m:5.0]	b:0, m:1.8 (m:1.2) [m:3.0]
Maximizing profit	$\mu=1$	b:16.0, m:27.0 (m:31.3) [m:4.8]	b:14.9, m:15.6 (m:14.9) [m:12.4]
	$\mu=1.2$	b:4.0, m:60.0 (m:31.3) [m:4.8]	b:13.8, m:15.2 (m:14.9) [m:12.4]
	$\mu=1.5$	m:60.0 (m:31.3) [m:4.8]	m:15.6 (m:14.9) [m:12.4]

Note: [a]The optimal frequency and fare of public transport modes during Ching Ming Festival (Chung Yeung Festival) [normal days], where b is for bus and m is for mini-bus.

visitors. To achieve a balance point of these two objectives, the government may consider setting a smaller value for the upper bounds on frequencies and fares to ensure that both the consumer surplus and profit are at acceptable levels if the government decides to let a private operator manage the feeder services.

4.3. Sensitivity of Logit Model Parameter

In order to identify the uncertainty of operating the public transport services based on the variations of road conditions (which affects the scaling factor μ associated with the in-vehicle travel time) and passengers' mode choice (which affects the logit model parameter θ), sensitivity tests were additionally carried out in this study. As demonstrated in Section 4.2, Case 4 offers the best improvement compared with current situation in both consumer surplus and profit optimization, it is thus selected for the following analysis.

The optimal annual consumer surplus and profit obtained under different values of μ and θ are plotted in Figures 3 and 4, respectively. As shown in the figures, as the value of θ increases from 0.5 to 1.5, the optimal annual consumer surplus slightly decreases (less than 0.1 million) and the optimal annual profit significantly increases (about 0.7 million). It shows that profit is more sensitive to θ compared with consumer surplus. The results present that the private operator, who aims to maximize the annual profit, has a higher uncertainty than that of the government to achieve their own objectives.

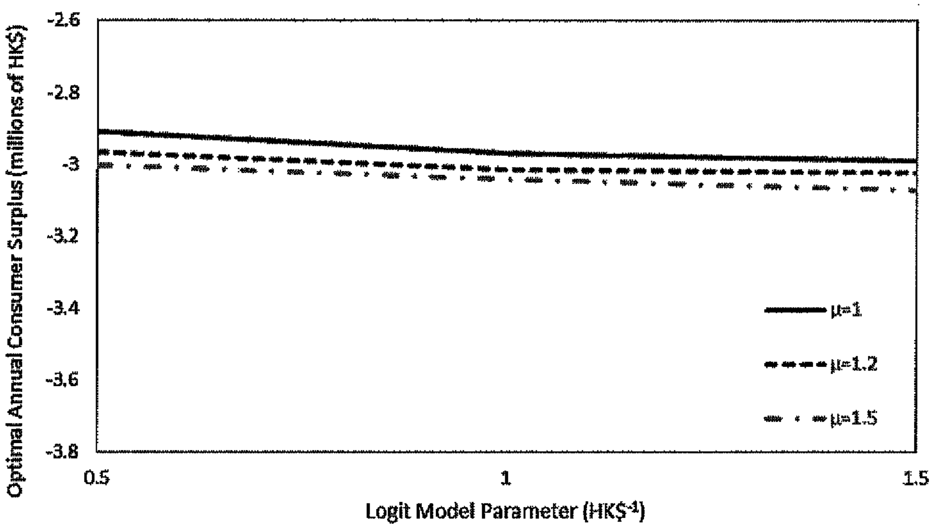

Figure 3. Optimal annual consumer surplus under different scaling factors of in-vehicle travel time and different logit model parameters

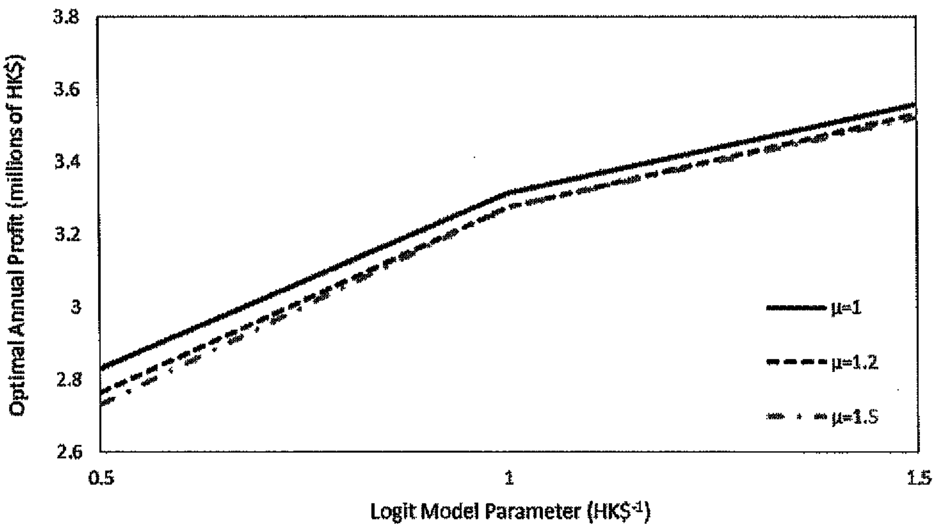

Figure 4. Optimal annual profit under different scaling factors of in-vehicle travel time and different logit model parameters

5. CONCLUSION

In this paper, an optimization framework is proposed to investigate the optimal temporary publvic transport arrangement for transporting the visitors between Yuen Yuen Institute columbarium and the nearest railway station for grave-sweeping. Two objectives of consumer surplus and profit are maximized separately and two public transport feeder services provided by bus and mini-bus are analysed. Variation in travel demand levels during different visit periods in a year is taken into account.

Numerical tests are carried out based on the survey data obtained during a grave-sweeping festival. Based on the model results, the performances of four cases of combinations of allowing adjustable fare and providing two public transport feeder services are identified and compared. It is found that the current public transport arrangement is neither optimal for consumer surplus nor profit. Potential improvement schemes are investigated based on the model results. The findings show that buses are usually more suitable for the visit period with a high travel demand (i.e., during Ching Ming Festival) while mini-buses are more effective if the travel demand is relatively lower (i.e., during Chung Yeung Festival and on normal days). To sum up, Case 4, which allows adjustable fare for different visit periods and provides multiple public transport feeder services, gives the best objective values among all cases (including the current situation). The finding suggests a direction for the policy makers to improve the current situation, which can be done by relaxing the operational restrictions of the existing feeder services. The service details of the optimal solution are also provided in this paper for reference.

This paper provides a valuable reference for the policy makers to judge whether the public transports should be offered by the government or a private operator. Frequency in consumer surplus optimization models tend to be as high as possible, which leads to high operational cost. On the other hand, fares in profit optimization models could be unreasonably high for the visitors. To achieve a balance point of these two objectives, the government may consider setting a smaller value for the upper bounds on frequencies and fares to ensure that both the consumer surplus and profit are at acceptable levels if the government decides to let a private operator manage the feeder services.

The results of sensitivity tests by inputting different scaling factors of in-vehicle travel time and logit model parameters show that profit is more sensitive compared with consumer surplus. The private operator, who aims to maximize the annual profit, has a higher uncertainty than that of the government to achieve their own objectives.

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