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OPTIMAL TRAIN STOPPING SCHEDULING FOR HIGH SPEED RAIL SYSTEMS

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Abstract
The optimal train stopping scheduling model is developed by integrating the interactive relationship between the train stopping scheduling and operations plan which includes the frequency, train fleets, and seats allocation plan. The model is a multiple objectives model which the objectives of operator's operating costs and the passenger's travel time loss are considered. The model can be used to analysis how many combinations of the train stopping scheduling is needed for various demand patterns. By the model, the efficient train stopping scheduling and operations plan is obtained simultaneously. This results reduce the 20% of operating cost and 327% of passenger's travel time loss.

INTRODUCTION

A high speed rail system is planned to be carried out in Taiwan in the future. The issues on the high speed rail system have been discussed extensively. Train stopping scheduling has a great influence on both the passenger's travel time loss and the operator's operating cost. The capacity of the system, layout of stations, and the operations plan which includes the frequency, train fleets, and seats allocation plan are based on train stopping schedules.

If passengers are served by the express train, the frequency and operating cost are increased, and the passenger's travel time loss is reduced. On the other hand, if the local train provides service for passengers, the frequency and operating cost are reduced, and the passenger's travel time loss is raised. The higher train capacity and fewer frequency provide the same capacity for passengers as the lower train capacity and more frequency. Passengers between two stations can be served by the various train stopping schedule. Thus, the combinations of the train stopping scheduling and operations plan are enormous. Their performance differs greatly from each other. So, it is very difficult to determine the efficient one.

In determining the operations plan, the train stopping schedule and operations plan are usually determined separately. The train stopping schedule is determined according to the demand pattern. Then the operations plan is worked out on a basis of the train stopping schedule. Because the interactive relationship between the train stopping schedule and the operations plan is ignored, the operations plan and the train stopping schedule determined is often inefficient. In addition, it is very difficult to obtain an efficient train stopping schedule when the demand distribution pattern is many-to-many. To decrease the operating cost and passenger's travel time loss, the train stopping schedule and operations plan should be determined simultaneously.

This research develops an optimal train stopping scheduling model which is integrated with the operations plan. The model is a multiple objectives model in which the objectives of operator's operating costs and the passenger's travel time loss are considered. The model is solved by the fuzzy multiobjective programming which is combined with the augmented max-min operator to guarantee a nondominated compromise solution. Optimal solutions of the model include the train stopping schedule, frequency, vehicle fleets, and seats allocation, which are determined simultaneously according to the many-to-many demand distribution pattern. An empirical research is undertaken for the high speed rail system in Taiwan. The model can be used to analyze how the operator's operating costs and the passenger's travel time loss are affected by the train stopping scheduling. The optimal combinations of the train stopping schedule is worked out for the different demand distribution pattern by the model. The model can be also used to analyze how the train stopping schedule and the operations plan are affected by train capacity, and to determine what the optimal train capacity of the system is.

THE OPTIMAL TRAIN STOPPING SCHEDULING MODEL

Model Formulation

A high speed rail system supplies trains to run on the elevated railway. The train makes a short stop at several stations, and passengers board on and alight from the train. Figure 1 represents the railway route with N stations. The station 1, s, and N are the initial station, shunting station and the terminal station respectively. They can be used as the initial stations. Station i and j are intermediate stations. Trains depart from the initial station , pass and stop several stations, and arrive at the shunting or terminal station. Then the train returns to the initial station form the shunting or terminal station. Several combinations of train stopping schedule are used to provide service for passengers. The trains departing from the initial station s (s = 1, 2, ..., S) run according to the train stopping schedule r (r = 1, 2, ..., R) during period t at a uniform frequency f_{trs}. The duration of period t is P_t. The time for stops is S_i minutes. The demand volume is uniformly distributed within each period t (t = 1, 2, ..., T) (e.g., morning peak, midday, afternoon peak, night). Passengers from station i to j served by the train stopping schedule r during period t is defined as d_{ijtrs}, Which is used as a basis for seats allocation. The total demand volume from station i to j is defined as D_{ijt}.

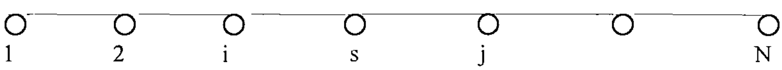

Figure 1 - The railway route

The train makes a short stop at several stations. This increases the passenger's travel time. The passenger arrives at the station to board the train according to the train table time. Thus the passenger's waiting time is very short. In developing the optimal train stopping scheduling model, we assume the operating time between stations i and j is constant. The passenger's travel time loss is used to develop the passenger's objective. On the other hand, the variable operating cost is used to establish the operator's objective, and the construction cost of the system is not considered. We also assume that the demand is given and is not affected by the operations plan. The stop variable x_{itrs} is used to established train stopping schedule r. x_{trs} =1 indicates the train stops at station i, and x_{trs} =0 indicates the train does not stop at station i. By the model , frequency f_{trs}, stop variable x_{itrs}, train fleets n, and passenger served d_{tijtrs} are determined simultaneously. The model is formulated as:

$$MIN \quad Z_1 = \sum_{t=1}^{T}\sum_{s=1}^{S}\sum_{r=1}^{R} 2 \cdot F_{tr} \cdot P_t \cdot M_{trs} + C_o \cdot P_t \cdot n \tag{1}$$

$$MIN \quad Z_2 = \sum_{t=1}^{T}\sum_{s=1}^{S}\sum_{r=1}^{R}\sum_{i=S+1}^{N-1} S_i \cdot P_t \cdot D_{itrs} \tag{2}$$

Subject to

$$L_{si} \cdot f_{trs} - M \cdot (1 - x_{itrs}) \le M_{trs} \tag{3}$$

$$\sum_{p=1}^{i-1}\sum_{q=i+1}^{N} d_{pqtrs} \cdot R_{pqtrs} + \sum_{q=i+1}^{N}\sum_{p=1}^{i-1} d_{qptrs} \cdot R_{qptrs} - M(1 - x_{itrs}) \le D_{itrs} \tag{4}$$

$$\sum_{s=1}^{S}\sum_{r=1}^{R} d_{ijtrs} \cdot R_{ijtrs} = D_{ijt} \tag{5}$$

$$\sum_{i=s}^{N} x_{itrs} \le (N-s)\cdot x_{str} \tag{6}$$

$$f_{trs} \le M \cdot x_{str} \tag{7}$$

$$\sum_{j=1}^{N} d_{ijtrs} + \sum_{j=1}^{N} d_{jitrs} \le M \cdot x_{itrs} \tag{8}$$

$$\sum_{s=1}^{S}\sum_{r=1}^{R} f_{trs} \le K_a \tag{9}$$

$$\sum_{p=s}^{j-1}\sum_{q=j}^{N} d_{pqtrs} \le Q_{tr} \cdot f_{trs} \tag{10}$$

$$\sum_{p=s}^{j-1}\sum_{q=j}^{N} d_{qptrs} \le Q_{tr} \cdot f_{trs} \tag{11}$$

$$(1+R_O)\sum_{s=1}^{S}\sum_{r=1}^{R} 2\cdot(1+T_O)\cdot f_{trs} \cdot \max_{i=s+1}^{N}\left(T_{si} \cdot x_{itrs} + \sum_{i=s+1}^{N-1} S_i \cdot x_{itrs} \right) \le n \tag{12}$$

(1) and (2) are the two objectives of the model. (1) is to minimize the operator's operating cost. The operating cost is related to both the train fleets n and train operating distance M_{trs} for each train stop scheduling. The cost related to the train operating distance includes the fuel consumption, labor and management of train operations, determined by the units cost F_{tr}, the frequency f_{trs}, and the duration of period P_t. The cost related to train fleet including the train repaired cost and depreciated cost are determined by the unit cost C_O, train fleets n, and the duration of period P_t. (2) is to minimize the passenger's travel time loss which is obtained by multiplying the time for stops S_i, passengers on train D_{itrs} when the train stops at station *i*, and the duration of period P_t.

(3) characterizes the train operating distance M_{trs} for each train stopping scheduling *r*. The M_{trs} is determined by the distance L_{si} between the initial station *s* and the terminal station, the frequency f_{trs}, and the terminal station variable x_{itrs}. The terminal station variable is an 0-1 integer variable. x_{itrs} =1 indicates the train stops at station *i*, and x_{itrs} =0 indicates the train does not stop at station *i*. The arbitrary large number *M* assures the train operating distance for each train stop schedule *r* is obtained by maximizing the M_{trs}. Constraint (4) specifies the passengers on the train D_{itrs} when the train stops at the station *i*. The D_{itrs} is determined by the passengers between stations *p* and *q* who use the train stopping schedule *r* (R_{pqtrs}=1), and passengers go through station *i*. When x_{itrs} =1 indicates the train stops at station *i*, then the travel time of the D_{trs} is increased by the time for stops. When x_{trs} =0 indicates the train does not stop at station *i*, the D_{trs} =0 by the arbitrary large number *M*. (5) assures that passengers D_{trs} between station *i* and *j* during the period *t* must be served by the train stopping schedule. (6) and (7) specify all trains must depart from initial stations. The initial station variable x_{trs} is an 0-1 integer variable. x_{trs} =0 represents the train stopping schedule cannot be formed, and the frequency is equal to 0. x_{trs} =1 represents the train stopping schedule is formed. (8) specifies the train stopping schedule *r* does not stop at station *i*, and the passenger of the station *i* cannot board on and alight from the station *i*. (9) is a capacity

limitation on the train K_a which can be accommodated in the route and terminal. (10) and (11) constitute the service capacity, which must be at least as great as the passengers on the train in the in-bound and out-bound. The service capacity is determined by the train capacity Q_{tr} and frequency f_{trs}. (12) represents the train fleets n. With the operating time L_{si} between initial station s and terminal station, the time for stops S_i,and the station variable x_{itrs}, the cycle time of the train stopping scheduling is determined. The number of trains is more than the product of the cycle time, the ratio T_o of terminal time and cycle time, and the ratio R_o of the repairing train and train fleets. Table 1 shows the definition of variables used in the optimal train stopping scheduling model

Table 1 - Variables definition of the optimal train stopping scheduling model

Symbol	Definitions
Z_1	= objective of the operating cost, \$/day
Z_2	= objective of passenger's travel time loss, hour/day
C_o	= cost related to the train, \$/train-day
D_{ijt}	= passengers between station *i* and station *j* during period *t*, passengers/hour
D_{itrs}	= passengers on the train when train stop at station *i*, passenger/hour
d_{ijtrs}	= passengers served by the train stopping scheduling *r* during period *t*, passenger/hour
F_{tr}	= operating unit cost related to the train operating distance, \$/train-km
f_{trs}	= frequency of the train stopping scheduling *r* during period *t*, train/hour
K_a	= station and line capacity, trains/hour
L_{si}	= distance between the station *i* and initial station *s*, km
N	= number of stations
n	= train fleets, train.
M	= an arbitrary large number
M_{trs}	= train operating distance of the train stopping scheduling *r* during period *t*, km
Q_{tr}	= train capacity of the train stopping scheduling *r* during period *t*
R_o	= ratio of the repairing train and train fleets
R_{ijtrs}	=1, train stopping schedule *r* can serve passengers between stations *i* and *j* during period *t* =0, train stopping schedule *r* cannot serve passengers between stations *i* and *j* during period *t*
r	= number of train stopping scheduling, *r*=1,2,...,R
S_i	= time for station *i*, minute
t	= number of period, 1,2,...,T
T_o	= ratio of terminal time and cycle time
T_{si}	= operating time between initial station *s* and station *i*, hour
x_{itrs}	=1, station *i* is served by the train stopping schedule *r* during period *t* =0, station *i* is served by the train stopping schedule *r* during period *t*

Solution Procedure

In fuzzy multiobjective programming, the most frequently used aggregation operator is the 'Max-Min' operator proposed by Zimmermann (1978). This operator cannot guarantee a nondominated solution and is completely noncompensatory (Lee and Li, 1992). Recent empirical research (Luhandjula, 1982) indicates that both the minimum and product operators are not very appropriate to model the use of the fuzzy 'AND'. It is much more desirable if a compensatory operator is used to obtain the compromise solution. We suggest the Augmented Max-Min operator (Lai and Hwang, 1992) to solve the compromise solution. The compensatory operators have been used to obtain a compromise solution between conflicting objectives (Lee and Li, 1992; Bit et al., 1993; Chang and Shen, 1994). It allows compensation to a certain extent between aggregated membership functions of objectives. It also guarantees the compromise solution is a nondominated one. It is used to transform the fuzzy multiobjective model for the optimal train stopping scheduling model into a single objective model. To obtain the compromise solution from the model, a procedure is devised as:

Step 1. Solve the fuzzy multiobjective model as a single objective model, using only one objective at a time. Determine the corresponding values for every objective at each optimal solution.

Step 2. Establish the positive ideal solution of the model is shown as Table 2, and obtain the lower bounds L_k and upper bounds U_k, corresponding to a set of solutions for k^{th} objective.

Table 2 - Payoff table of positive ideal solution

	$Z_1(x)$	$Z_2(x)$	X
max Z_1	$Z_1(x_1^*)$	$Z_2(x_1^*)$	x_1^*
min Z_2	$Z_1(x_2^*)$	$Z_2(x_2^*)$	x_2^*
	U1=max ($Z_1(x_1^*)$, $Z_1(x_2^*)$)	U2=max ($Z_2(x_1^*)$, $Z_2(x_2^*)$)	
	L1=min ($Z_1(x_1^*)$, $Z_1(x_2^*)$)	L2=min ($Z_2(x_1^*)$, $Z_2(x_2^*)$)	

Step 3. Use (13) and (14) to constitute the membership function $\mu_k(x)$ (k=1,2) for the k^{th} objective, respectively.

$$\mu_1 = \begin{cases} 1 & if\ Z_1 \le L_1 \\ 1-\dfrac{Z_1-L_1}{U_1-L_1} & if\ L_1 < Z_1 < U_1 \\ 0 & if\ Z_1 \ge U_1 \end{cases} \tag{13}$$

$$\mu_2 = \begin{cases} 1 & if\ Z_2 \le L_2 \\ 1-\dfrac{Z_2-L_2}{U_2-L_2} & if\ L_2 < Z_2 < U_2 \\ 0 & if\ U_2 \le Z_2 \end{cases} \tag{14}$$

Step 4. Use the Augmented Max-Min operator to aggregate the membership functions of the objectives into a single membership function by (15).

$$\begin{aligned} &\text{MAX} \quad \lambda + \frac{\delta \sum_{i=1}^{2} \mu_i}{2} \\ &\text{Subject to} \\ &\quad \lambda \le \mu_1 \\ &\quad \lambda \le \mu_2 \end{aligned} \tag{15}$$

Step 5. The resultant model is given below. Solve the fuzzy multiobjective model by the LINDO software to obtain the compromise solution.

$$\text{MAX} \quad \lambda + \frac{\delta \sum_{i=1}^{2} \mu_i}{2}$$

Subject to

$$\lambda \le \mu_1$$

$$\lambda \le \mu_2$$

$$\mu_1 = \begin{cases} 1 & \text{if } Z_1 \le L_1 \\ 1 - \dfrac{Z_1 - L_1}{U_k - L_1} & \text{if } L_1 < Z_1 < U_1 \\ 0 & \text{if } U_1 \le Z_1 \end{cases}$$

$$\mu_2 = \begin{cases} 1 & \text{if } Z_2 \le L_2 \\ 1 - \dfrac{Z_2 - L_2}{U_2 - L_2} & \text{if } L_2 < Z_2 < U_2 \\ 0 & \text{if } U_2 \le Z_2 \end{cases}$$

$$Z_1 = \sum_{t=1}^{T} \sum_{s=1}^{S} \sum_{r=1}^{R} 2 \cdot F_{tr} \cdot P_t \cdot M_{trs} + C_o \cdot P_t \cdot n$$

$$Z_2 = \sum_{t=1}^{T} \sum_{s=1}^{S} \sum_{r=1}^{R} \sum_{i=S+1}^{N-1} S_i \cdot P_t \cdot D_{itrs}$$

Constraints (3)-(15)

CASE STUDY

An empirical research is conducted for the high speed rail system in Taiwan. The route of high speed rail system is shown in Figure 2. Table 3 shows the passenger demand volume . The train operating time between stations and the corresponding operating parameter are shown in Table 4 and Table 5 respectively.

When four train stopping schedules is given and fixed, Table 6 shows the operations plan obtained by minimizing the operating cost, and Table 7 shows the operations plan obtained by minimizing the passenger's travel time loss. To understand how the operating cost, the passenger's travel loss and operations plan are affected by the combinations of the train stopping schedule, the optimal train stopping schedule and operations plan are determined by the optimal train stopping scheduling model. Suppose the train stopping schedule is an unknown variable. Table 8 and Table 9 show the train stopping schedule and operations plan obtained by minimizing the operating cost respectively.

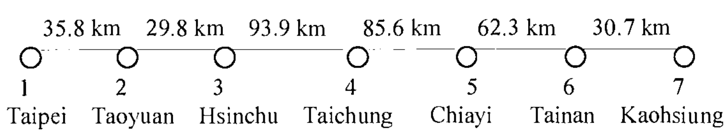

Figure 2 - The route planned for the high speed rail in Taiwan

Table 3 - The passengers design volume of high speed rail in Taiwan for 2030

O\D	Taipei	Taoyuan	Hsinchu	Taichung	Chiayi	Tainan	Kaohsiung
Taipei	0	683	737	1,407	483	636	2,257
Taoyuan	697	0	149	748	271	305	861
Hsinchu	603	111	0	320	53	64	242
Taichung	1,298	731	337	0	345	413	900
Chiayi	340	189	45	246	0	187	332
Tainan	513	270	68	295	222	0	591
Kaohsiung	2,105	776	241	768	465	817	0

Table 4 - The train operating time between stations (minutes)

O\D	Taoyuan	Hsinchu	Taichung	Chiayi	Tainan	Kaohsiung
Taipei	14	27	40	65	83	84
Taoyuan		11	36	61	79	83
Hsinchu			24	48	67	71
Taichung				22	40	44
Chiayi					17	29
Tainan						11

Table 5 - Operating parameters of the high speed system

Terminal Time (minutes/train)	45
Train Capacity (seats/train)	800
Station and Line Capacity (trains/hour)	15
Ttime for Stations (minute/station)	3
Units Cost Related Train Operating Distance ($/train-km)	91459.36
Units Cost Related Train ($/train-day)	201353

Table 6 - The optimal operations plan with four given train stopping schedules by minimizing the operating cost

Operating Cost ($/day)	16,599,350
Passenger's Travel Time Loss (hours/day)	20,588
Train Stopping Schedule (trains/hr) @	
A-G	3
A-D-G	3
A-B-C-D	3
A-D-E-F-G	4
Train Fleets (trains)	49

@:A: Taipei, B: Taoyuan, C: Hsinchu, D: Taichung, E: Chiayi, F:Tainan G: Kaohsiung

Table 7 - The optimal operations plan with four given train stopping schedules by minimizing the passenger's travel time loss

Operating Cost ($/day)	18,023,211
Passenger's Travel Time Loss (hours/day)	15,847.94
Train Stopping Scheduling (trains/hr)	
A-G	3
A-D-G	4
A-B-C-D	3
A-D-E-F-G	4
Train Fleets (trains)	53

Table 8 - The optimal train stopping schedules and operations plan by minimizing the operating cost

Train Stopping Schedules	Frequency (train/hour)	Operating Cost ($/day)	Passenger's Travel Time Loss (hours/day)	Train Fleets (train)
A-B-C-D-E-F-G	10	16,453,476	44,123.36	51
A-D	1	15,522,730	42,790.00	48
A-B-C-D-E-F-G	9			
A-B-C-D	1			
A-B-D-G	5	14,918,670	24,708.68	45
A-B-C-D-E-F-G	4			
A-D	1			
A-G	3	14,515,966	15,840.68	43
A-B-D-G	2			
A-B-C-D-E-F-G	4			
A-G	3			
A-C-D	1			
A-D-E-G	2	14,314,613	9,068.0	42
A-B-D-F-G	3			
A-B-C-D-E-F-G	1			

Table 9 - The optimal train stopping schedule and operations plan by minimizing the passengers' travel time loss

Train Stopping Schedules	Frequency (train/hour)	Operating Cost ($/day)	Passenger's Travel Time Loss (hours/day)	Train fleets (train)
A-B-C-D-E-F-G	10	16,453,476	44,123.36	51
A-D-G	6	17,273,280	19,543.44	52
A-B-C-D-E-F-G	5			
A-F-G	4			
A-B-D	4	16,870,576	11,763.14	50
A-B-C-D-E-F-G	3			
A-G	3			
A-D-F-G	3	18,495,790	8,735.34	55
A-B-E-F-G	3			
A-C-D-E-F-G	3			
A-D	2			
A-F-G	4			
A-B-C-F-G	1	15,210,427	7,471.34	45
A-B-D-E-G	3			
A-C-D-E-F-G	1			
A-D	2			
A-G	3			
A-B-F-G	2	15,009,705	3,708.02	44
A-B-D-E-G	1			
A-B-C-E-F-G	1			
A-C-D-F-G	2			

The results in Table 8 indicate the operating cost is $14,314,613, the passenger's travel time loss is 9,068 hours, the frequency is 10 trains and train fleet is 42 trains. By comparing the results of the Table 8 and Table 6, the operating cost is reduced by 15.96%, the passenger's travel time loss is decreased by 127%. The results in Table 9 indicate the operating cost is $15,009,705, the passenger's travel time loss is 3,708 hours, the frequency is 11 trains and the train fleet is 44 trains. In comparing the results in Table 9 with Table 7, the operating cost is reduced by 20.0%, the passenger's travel time loss is decreased by 327%.

From the results in Table 8 and Table 9, the objectives between the operating cost and passenger's travel time loss conflict with each other. When the operating cost is decreased by fewer frequency, the train stops more stations, and train fleets, thus the passenger's travel time loss is increased. To balance the objectives of the operator and the passenger, the optimal train stopping scheduling model with multiple objectives is solved by the multiobjective programming, and the results are shown in Table 10 and Table 11. Table 10 shows the ideal solutions for each objective. Table 11 shows the optimal train stopping schedule and operations plan. When the operating cost and passenger travel time loss are considered and balanced, the express service is provided for long-distance passengers, and the skip-stop service is provided for the medium-distance passengers, and the all-stop service is provided for the short-distance passengers.

Table 10 - Payoff table of positive ideal solution for the optimal train stopping schedule

	$Z_1(x)$	$Z_2(x)$
min Z_1	14,314,613	9,068.00
min Z_2	15,009,705	3,708.02
	U_1=15,009,705	U_2=9,068.00
	L_1=14,314,613	L_2=3,708.02

Table 11 - The optimal operations plan and train stopping schedule by fuzzy multiobjective programming

Operating Cost ($/day)	14,515,965
Passenger's Travel Time Loss (hours/day)	8,058
Train Stopping Schedule (trains/hr)	
A-G	2
A-F-G	1
A-C-D	1
A-D-E-G	2
A-B-D-F-G	3
A-B-C-E-F-G	1
Fleets (trains)	43

Table 12 shows the optimal train stopping schedule for various train capacities. If the optimal train capacity is 1,000 passenger per train, the operating cost is $13,959,331, and the frequency is 8 trains per hour and the train fleets is 33 trains. When the train capacity is 800 passenger per train, the frequency is 10 trains per hour and the train fleets is 42 trains. When the train capacity is increased to 1,400 passenger per train, the frequency is decreased to 6 trains per hour and the train fleets is 25 trains. When the train capacity is increased from 800 passenger per train to 1,100, the combinations of train stopping scheduling is decreased and the number of stops is reduced. The difference on the operating cost is 11.6%, on the frequency is 40.0%, and on the train fleets is 40.0%. This indicates the train capacity has a great influence on the operating cost, frequency, train fleets, and combinations of the train stopping scheduling.

CONCLUSION

The relationship between the train stopping schedule and operations plan is complex for many-to-many demand distribution pattern. The train stopping schedule has a great influence on the operating cost, passenger's travel time loss, and operations plan. If the train stopping schedule and the operations plan are determined separately, the inefficient train stopping schedule and operations plan is obtained, and the operating cost and the passenger's travel time loss are increased greatly.

Table 12 - The optimal train stopping scheduling and operations plan for various train capacity

Train Capacity (passenger/train)	Train Stopping Schedule	Frequency (train/hour)	Operating Cost ($/day)	Train Fleets (train)
	A-G	3		
	A-C-D	1		
800	A-D-E-G	2	14,314,613	42
	A-B-D-F-G	3		
	A-B-C-E-G	1		
	A-D	1		
900	A-D-G	5	14,254,349	38
	A-B-F-G	1		
	A-B-C-D-E-F-G	2		
	A-D-G	4		
	A-B-D	1		
1,000	A-B-E-G	1	13,959,331	33
	A-B-C-F-G	1		
	A-C-D-E-F-G	1		
	A-B-D	1		
1,100	A-B-F-G	2	15,577,530	34
	A-D-E-G	4		
	A-B-C-D-E-F-G	1		
	A-G	3		
1,200	A-B-D	1	14,547,080	29
	A-B-D-F-G	1		
	A-B-C-D-E-F-G	2		
	A-D	1		
1,300	A-F-G	4	15,723,408	29
	A-B-D-F-G	1		
	A-B-C-D-E-F-G	1		
	A-B-D	1		
1,400	A-D-G	2	14,452,585	25
	A-C-F-G	2		
	A-B-C-D-E-F-G	1		

In this research, an optimal train stopping scheduling model is developed. By the model, the efficient train stopping schedule and operations plan are obtained simultaneously. The result of the model reduces 20% of operating cost and 327% of passenger's travel time loss. When the operating cost and passenger travel time loss are considered and balanced, the express service is provided for long-distance passengers, the skip-stop service is provided for the medium-distance passengers, and the all-stop service is provided for the short-distance passengers. To achieve a better performance, it is needed to provide suitable train stopping schedule according to the demand pattern.

The model can be used to analyzes how many combinations of the train stopping schedule is needed for various demand patterns. The empirical study conducted on the high speed rail system in Taiwan indicates that the train capacity has a great influence on the operating cost, frequency, train fleets, and combinations of the train stopping schedule.

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