科技學刊　第 16 卷 科技類 第 4 期　頁 301-307 中華民國 96 年 11 月

A MIXED-MODEL PRODUCTION WAY FOR OPERATIONS ON VEHICLES DISPATCHING

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ABSTRACT

Heaps of the just-in-time (JIT) concepts have been successfully deployed in manufacturing industries for decades, and one of the important techniques among them is the mixed-model production planning. A mixed-model production line for manufacturing means that one single line is capable of making several different parts for a given period of time. However, the mixed-model production idea may also be helpful to solve the imbalance between service supply and passengers demand in urban bus operations. In this paper, an overview on the technique of mixed-model is provided, and moreover, several scheduling scenarios including mixed-model ones are planned. As a numerical demonstration, one typical exclusive bus lane in Taipei city is taken for analysis under the proposed scenarios. The results show that with a minibus service participation rate of 25%, the mixed-model dispatching could raise the operation efficiency to the 95% high, comparing to a present value of 85.43%. Moreover, the study shows that only by the mixed-model dispatching method, the gap between inconsistent demand and supply could easily be tightened without any increase in staff and service facilities costs.

Keywords：just-in-time, mixed-model, operation efficiency, vehicles dispatching

Ⅰ. INTRODUCTION

Mixed-model scheduling method is a key element of just-in-time production. The single line which is capable of making several different parts for a given period of time is called mixed-model production line. It is often applied by companies to maintain diversified small-lot production to satisfy customers' demand for a variety of products, without holding large inventories, or to say, with less waste.

These mixed-model production lines use various production planning techniques to achieve the goals in today's manufacturing environments. These production planning techniques use different mathematical equations and formulas (Bukchin, et al., 2002; Miltenburg and Sinnamon, 1989, 1995) and even some complex algorithms to deliver the optimal solutions. Moreover, computer simulation is also a more and more popular method to perform a mixed-model production system (Watson and Wood, 1995). The evolution of short-term production planning techniques emerges as optimization, heuristic, complexity and interactive scheduling periods, as shown in Table 1.

Table 1　Development of Scheduling Techniques

Era	Control	Approach	Technique
Optimization	Hierarchical	Automatic	Optimization or heuristic
Heuristic	Hierarchical	Automatic	Heuristic
Complexity: artificial intelligence	Hierarchical	Automatic	Heuristic
Interactive schedulers	Distributed	Interactive	Heuristic + operator

Source: Caridi and Sianesi, 2000.

With regard to the urban bus services, the mixed-model scheduling concept may also be helpful to meet variable and unpredictable passenger demands. Some studies have tried to use fuzzy clustering technologies in response to variances in passenger demand attributes and traffic conditions (Sheu, 2005); however, it needs many on road and on bus facilities to collect the real time data, and might be difficult and expensive. Therefore, with the developed mathematical analysis framework combining optimization and interactive control ideas, this paper aims to plan some mixed-model scheduling scenarios for bus services in Taipei city, and to analyze the possible application potentials and limitations. It is obviously to find that the mixed-model production way to schedule the buses is a more easy and costless way to meet the variable passenger demands. As shown in Figure 1 (Andrle, 1999), with the mixed-model method, "passenger loading," "vehicle type & size," "on-board circulation" and "bus volume" will also be changed. Therefore, the "loading area vehicle capacity" and "bus stop vehicle capacity" could be changed accordingly to deliver a better service.

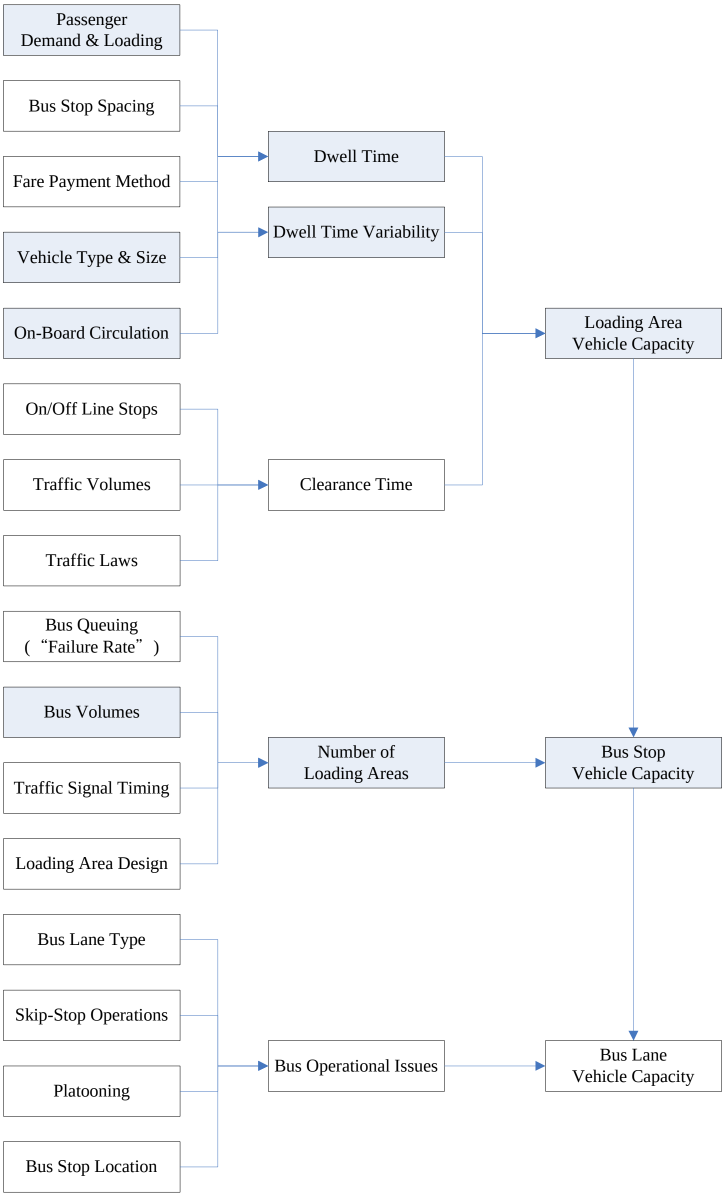

Figure 1 Bus Vehicle Capacity Factors

Source: TCRP Research Results Digest 35, TRB, 1999.

Ⅱ. MIXED-MODEL METHODOLOGY FOR BUSES SCHEDULING

A mixed-model method can produce more flexible and suitable capacities, neither too high nor too low. Moreover, if the mixed-model scheduling makes very little variability gap between demand and supply, it is called to level or balance the schedule, also named the leveled mixed-model production. Theoretical concepts of mixed-model with un-leveling and leveling are shown as Figure 2.

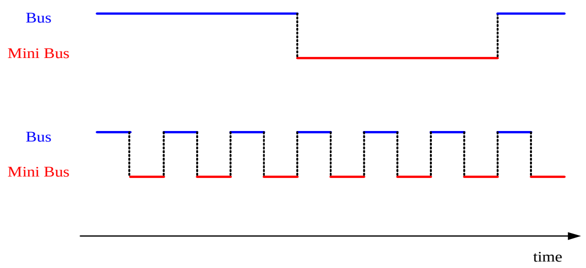

Figure 2　Mixed-Model Scheduling

In addition, Figure 3 shows the benefits of small lot mixed-model production. For the current, bus size is always fixed in the same service line and this causes exceeding or insufficient supply capacities. By the means of mixed regular size bus and minibus services in a same route, supply capacities will be more flexibly and accurately responded to the passenger demands.

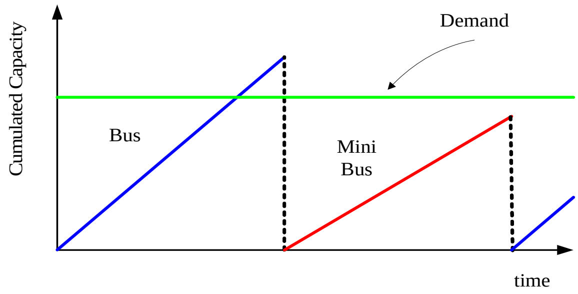

Figure 3　Mixed-Model Capacities

To apply the mixed-model production concepts on bus services, a mathematical analysis framework is developed in this study. Definitions of variables and parameters accompanied by some baseline values of the RenAi road exclusive bus lane in Taipei city are listed in Table 2. Note that variables or parameters which are left blank on the baseline value columns mean that they are dependent variables or there exists no single specific value for them.

Ⅲ. NUMERICAL DISPATCHING SCENARIOS ON TAIPEI CITY

"The RenAi Road Exclusive Bus Lane" in Taipei city is taken to present the scenario analysis. This bus lane, with 3.1 km long, serving from 5-24 o'clock, was finished in July 1996. In 2005, there were totally 579,906 frequencies of regular size buses served on it (i.e., 1,589 buses per day, or 84 buses per hour) and the net hourly demand mounted to 4,191 passengers.

Table 2　Definition of Variables and Parameters

Symbol	Statement	Baseline Value
C_b	capacity of regular size buses (passengers per vehicle, including seated and standees)	56
C_m	capacity of minibuses (passengers per vehicle, including seated and standees)	23
d_i	deviation factors of hourly passenger numbers	
D_i	adjusted passenger numbers on i th service hour, i =1- n	
$\overline{D}$	average passenger number per service hour	4191
e	operation efficiency indicator (%)	
h	headways of minibuses and regular size buses (min.)	$\frac{60}{84}$
S_i	capacity supply on i th service hour, i =1- n	
t	hourly service minutes of minibuses	
n	gross service hours in a single day (hr.)	19
N	gross bus numbers per service hour (vehicles)	$\frac{60}{h}$

To simulate the hourly demands, peak hour adjustment factors of hourly passenger numbers for the numerical case in this study are assumed as [1, 1.2, 1.5, 1.8, 1.2, 1.1, 1.1, 1.1, 1.1, 1.1, 1.1, 1.2, 1.5, 1.8, 1.5, 1.2, 1.1, 1.1, 1] for each of the daily 19 service hours. Furthermore, it can be processed as: 4191*19/ (19+0.2*4+0.5*3+0.8*2 +0.1*8)=3224 passengers. In other words, 3224 passengers now stand for the hourly passengers with the peak hour adjustment factor 1. Accordingly, “d_i” for each hour can be obtained as [0, 645, 1612, 2579, 645, 322, 322, 322, 322, 322, 322, 645, 1612, 2579, 1612, 645, 322, 322, 0] passengers. And finally, individual hourly passenger demand can be calculated from Equation 1.

$$D_i = \overline{D} + d_i \tag{1}$$

To compare the differences between the current service pattern and mixed-model services, three scenarios are proposed as “simple scheduling with regular size buses (i.e., the current service pattern),” “simple scheduling with minibuses (i.e., the antithesis pattern),” and “mixed-model scheduling.” They are discussed as below:

3.1 Simple Scheduling with Regular Size Buses

This is the current service pattern in RenAi road, Taipei. In this scenario, hourly capacity supply is obtained as Equation 2. In addition, indicator “e” is developed to analyze the operation efficiency of bus services, as shown in Equation 3.

$$S_i = \frac{60C_b}{h} \tag{2}$$

$$e = \left|1 - \left|\frac{\sum_{i=1}^{n} S_i - \sum_{i=1}^{n} D_i}{\sum_{i=1}^{n} S_i}\right|\right| \times 100 \tag{3}$$

In accordance to the current service pattern, passenger demand and service supply are shown as Figure 4. It is found that in most time, the supply is exceeding passenger demand to cause the waste of capacity. Meanwhile, the operation efficiency is 85.43% in the current service pattern.

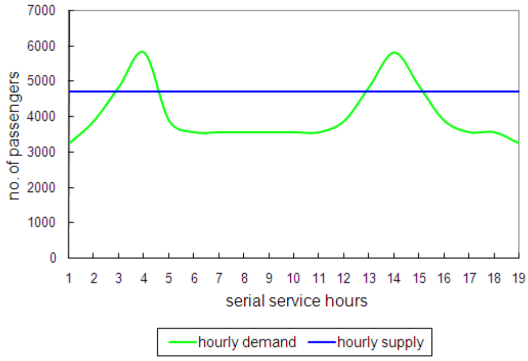

Figure 4 Demands vs. Supply Capacities under Current Service Pattern

3.2 Simple Scheduling with Minibuses

In this scenario, the hourly passenger demand is also calculated from Equation 1, while the hourly capacity supply is obtained with Equation 4.

$$S_i = \frac{60C_m}{h} \tag{4}$$

With regard to the fully minibus service pattern, passenger demand and service supply are shown as Figure 5. It is found that, by the same fleet size and available drivers, the supply is always less than passenger demand and leading the bad service for passengers. Undoubtedly, the operation efficiency slumps to the poor 8.15% in this service pattern.

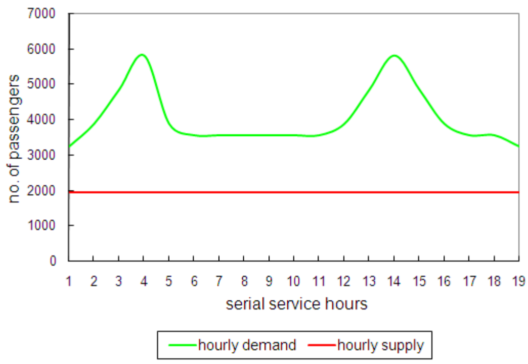

Figure 5 Demands vs. Supply Capacities under Fully Minibus Service

3.3 Mixed-Model Scheduling

In the mixed-model scenarios, the hourly passenger demand is still calculated as Equation 1. However, the gross hourly capacity supply of regular size buses and minibuses come together to be Equation 5.

$$S_i = \frac{(60-t)C_b}{h} + \frac{tC_m}{h} = \frac{(60-t)C_b + tC_m}{h} \quad (5)$$

In the mixed-model service pattern with different minibus service participations, passenger demand and service supply are shown as Figure 6. It is found that on the view of capacity balance, when hourly service minutes "t" ranges from 10-20 minutes, i.e., a 17%-33% participation rate of minibus service, the supply capacity can cover the greater part of demand. For Figure 7, it is found that, by the same fleet size and available drivers, the mixed-model service keep the service efficiency on mend if the participation of minibus is less than 25 minutes, comparing to the operation efficiency of 85.43% in the current service pattern. In other words, when hourly service minutes range from 0-25 minutes, i.e., the recommended participation rate of minibus service is 0%-42%, if rough improvements are satisfied. Otherwise, when hourly service minutes range from 5-23 minutes, i.e., 8%-38% participation rate of minibus service is recommended to exceed 90% operation efficiency. Finally, when hourly service minutes range from 10-20 minutes, i.e., 17%-33% is the most recommended minibus participation rate to exceed the operation efficiency of 95%. Finally, in this case on RenAi road, it is also found that when the hourly service minutes of minibus is 15 minutes, i.e., a participation rate of 25%, is the best for the highest operation efficiency.

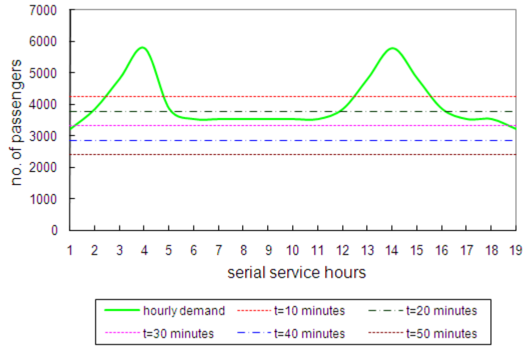

Figure 6　Demand vs. Supply Capacities under Varied Mixed-Model Scenarios

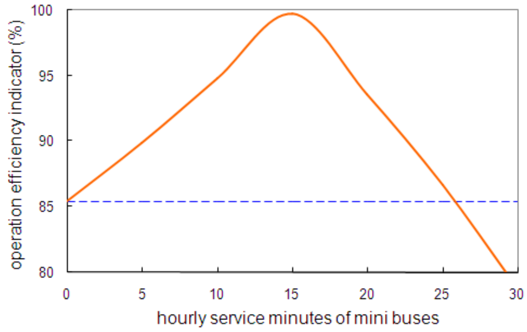

Figure 7　Operation Efficiency Indicators under Varied Minibus Service Participations

Ⅳ. CONCLUDING REMARKS

In this study, an overview on the mixed-model technique is provided, and moreover, mixed-model scheduling scenarios for urban bus operations are planned. With the simulated exclusive bus lane in Taipei city, it is found that for the urban bus services, the mixed-model scheduling concept could be also helpful to meet the variable and unpredictable passengers demand. In accordance to the analysis of this study, for an appropriate participation rate of minibus service, the mixed-model strategy always performs better than the conventional single model operations.

To highlight the benefits of mixed-model operations in this study, the available driving staff, bus and minibus headways are held the same for both the single model and mixed-model service scenarios. Under this assumption, it is found that without any increase on human resources and operating costs, the mixed-model scheduling method could effectively improve the current bus service. For more detailed, based on the point of capacity balance, a 17%-33% participation rate of minibus service is recommended to meet the passengers demand.

However, on the viewpoint of operation efficiency, the recommended participation rate of minibus service goes to 0%-42%, if simply rough improvements will be satisfied. Otherwise, the participation rate of 8%-38% is recommended to get the operation efficiency going beyond 90%. And furthermore, 17%-33% is the most recommended minibus participation rate which leads to exceed the operation efficiency of 95%. In accordance to these analysis data of this study, it is concluded that mixed-model service pattern should be pushed ahead to improve the operation efficiency in due course.

Finally, more detailed exploration of the mixed-model operation techniques and problems that will be encountered in real world operations, such as the service sequences of regular size bus and minibus, mixed-model scheduling with leveling, and etc., are not discussed herein. All these concerns are still worth the further studies.

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Received 12 November 2007
Revised 5 Mach 2008
Accepted 26 March 2008

混線生產模式應用於車輛派遣作業之研究

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摘　要

剛好及時 (JIT) 的生產概念在製造業已有數十年的成功應用經驗，而這當中最重要的一項技術則為混線生產排程規劃。製造業的混線生產方式意味著在特定期間內，單一生產線有能力生數種產不同之零組件或成品。然而，若將混線生產概念用來解決供需不平衡之市區公車派遣作業或許也有其效益；亦即藉由小型公車與標準車型公車之混線派遣方式將能獲得比現有單純以標準車型公車派車具有更佳的服務效率。有鑑於此，本研究首先對以往的製造業混線生產排程規劃技術進行回顧，接著提出混線生產方式應用於市區幹線公車車輛派遣之可行架構，最後並選定台北市一條典型的公車專用道幹線擬定數種服務情境以進行服務效益分析。就數值分析結果顯示，若小型公車佔總派遣公車數約 25%時，以混線方式進行派車將可使營運效率由目前的 85.43%提升至 95%。本研究顯示在不增減現有服務人力與相關設施成本之條件下，只要藉由混線車輛派遣方式，就能減緩供需不一致之缺口，進而有效提升服務效能。

關鍵詞：剛好及時、混線、營運效率、車輛派遣