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Regional bus line optimize model integrating timetable and vehicle scheduling

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Abstract: Bus timetable and vehicle scheduling is the base of security and efficiency to enterprises. It is necessary to take into account both the passenger travel demand to meet the social and economic benefits of bus enterprises. Common travel area path of the bus lines chosen as the research target of this article, based on the grid lines to establish the corresponding optimization model line of vehicles to the station for the departure of non-synchronous time model. The optimization model consider the operating costs and passenger demand, in order to avoid wasting a large interval caused by arrival time conflict or a large interval, which results in a vehicle passenger waiting time is too long. The proposed model for the design of the corresponding heuristic algorithms, and through practical examples of public transport network is provided to demonstrate the validity of model and solution algorithm.

Keywords: Departure Time, Objective Optimization, Operation Optimization; the Same Route Bus Line

1. Introduction

As urban development continuing to accelerate, people's increasing demand for travel, urban transport, especially in urban public transport is also facing increasingly heavy pressure and responsibility. Reasonable and effective public transport operation and management can effectively alleviate passenger congestion and reduce the cost of public transport enterprises running their own. Organized bus runs daily schedule is the core to improving the effectiveness of urban transport travelling environment, reasonably and effectively.

Many previous studies (Bodin et al., 1983) just stay in the single bus timetables to each bus lines only according to their posting schedule to run daily traffic Such method has some disadvantages: ① Insufficient research on regional transport network, because the travel transport network in the selection of bus routes and alignments only related to the travelers. That means passengers may have multiple lines of options; ② No considering in the total number of lines running between the bus lines between cooperation and competition, so there is no maximum was rational use of available resources to optimize the allocation of transport capacity to save operating costs. Increasing demand in the bus today, this single method of preparation began to expose their own lack of public transport network as key to the development of operations. It needs to be in a certain area bus routes into the integrated coordination. According to different lines within the region, sending off time, the staff can be exercised on the number of lines and the number of vehicles to determine the line with cars, the grid frequency and scheduling personnel and passengers work to balance the profits between bus passengers and bus companies, to reduce operating costs, to reduce costs of passenger and improve the passenger travel business profits.

Article to share a common path of the bus lines run as the research object to the peak section of the city during peak hours to study the situation on the basis of passenger traffic in order to optimize the regional bus departure time. Arrival timetable were line spacing for the design objectives, simultaneously using a reasonable method to establish a viable and effective regional transportation system in the schedule generation model. Be advised that papers in a technically unsuitable form will be returned for retyping. After returned the manuscript must be appropriately modified.

2. Analysis and Hypothesis

2.1. Analysis

To improving the bus network operations optimization, bus operators need to be carried out in accordance with the corresponding time and space division ,which can be the basis of different periods, different areas and passenger travel demand characteristics to make personnel, vehicles and departure time, departure frequency reasonably and effectively. By the time the bus lines for the supply and demand for more transport capacity match, the entire line can be divided into a number of operating time interval. On this basis, according to characteristics of different periods, we can set the parameters the preparation of the corresponding schedule line. There are a lot of research (Situ & Jin, 2010) (Xu, 2009), commonly used method for historical experiences by law. By bus lines in space, it is the public transport network foundation and core operations. Larger space in the context of the land in accordance with the nature of different regions, travel features, traffic and other elements to the large region is divided into several smaller regional, and ultimately determine the degree of correlation in the circuit, by a certain area of the bus lines, which run the bus lines were lines, there are up to optimize and adjust the space, because the passengers up and down For the total segment of travellers, they concerns only the beginning of travel and focus for this part of the crowd, in total in any way bus line can be a choice of travel, then the reasonable optimization segment bus lines total departure time, the site of the vehicle to achieve the asynchronous and high, no doubt to reduce passenger waiting time, improving transit service levels, while public transport enterprises not to increase or even reduce operating costs. This article is from bus lines run a total line segment, the impact of different bus lines and the collaboration between the research points to start, build, including the departure time model and vehicle headway model.

2.2. Assumptions

1. Road conditions normal, no special events, public transportation vehicles that can run on the line according to the design speed, according to schedule arrival.

2. All the more lines of vehicles will not be the case of stations and overtaking.

3. In the total vehicle operating segment, it is the same model that has a passenger capacity of the same rated.

4. All passengers choose different line segments were equal probability

5. Not to consider the impact of people existing on the site to people coming to the site, the default is that people who are coming to the site will enter the queue of passengers waiting.

3. Model and Algorithm

3.1. Model

To develop public transportation, by strengthening the network of public transport operation and management, to encourage and induce more bus passengers to travel routes using reasonable choice. We can reduce the peak number of passengers stranded of some stations by adjusting and optimizing the schedule(Zhang, 2009; Lv et al., 2009), sharing line operating pressure to reduce fluctuations in the number of vehicle to improve the line load factor and reducing passenger waiting time, improving bus service quality. For the collinear lines running, the ideal state is to stagger the arrival times of different lines of vehicles to avoid traffic concentration wasting(Liu & Shen, 2007), it also should avoid that site for a long time without the vehicle come caused by the arrival. All of such phenomenon would make passengers waiting too long and reduce bus service levels. So what we need to do is to minimize the time difference on arrival of vehicles at the fluctuations of the order to achieve the average. If the passenger should have produced the inevitable changes in the wave arrival time difference, they should try to make this kinds of fluctuations become relatively flat. The events which is bad to the quality of transit service such as average waiting time for passengers to travel relatively less concentration of vehicles arriving or a site that is not conducive to raising a large interval should be avoided.

Our objective function is to get a different time line to reach different sites scattered as far as possible and make the minimum time difference fluctuations. In order to be acceptable to the objective function value, we need the following steps, and gradually get the optimal solution calculated.

1. Construction of bus lines network structure G (N, M)

- --N expressed as a transit network in the set of all collinear lines
- --M is expressed as total public transport network in the line of site, a collection of all

2. Built on a total area of each line segment, each frequency, to reach a total of Line station sites all the time matrix T, and total segment according to the first station in the order of their arrangement.

$$T=\begin{pmatrix} x_1+t_{11} & \dots & x_n+t_{1n} \\ \vdots & \ddots & \vdots \\ x_1+t_{m1} & \cdots & x_n+t_{mn} \end{pmatrix}$$

- --n means, after the first segment of a total order of the station's vehicles
- --m is expressed as that the current station line in the station is the order of sequence
- --X_n means after the first segment of a total station, the sequence is n the beginning of bus departure time
- --T_{mn} means the sequence for the n vehicles, starting from the starting point to reach the first m-line stations were required for the formation time. If i

was not in the station which the vehicles are to stay in the line, it will be instead of" * ".

3. To get the arrival time of the adjacent bus arrival time difference, we make a little adjustment of the above matrix, for the same site, adjacent to the arrival time difference of arrival frequency matrix W

$$W=\begin{pmatrix} (x_1+t_{11})-(x_2+t_{12}) & \cdots & (x_{n-1}+t_{1,n-1})-(x_n+t_{1n}) \\ \vdots & \ddots & \vdots \\ (x_1+t_{m1})-(x_2+t_{m2}) & \cdots & (x_{n-1}+t_{m,n-1})-(x_n+t_{mn}) \end{pmatrix} = \begin{pmatrix} y_{11} & \cdots & y_{1j} \\ \vdots & \ddots & \vdots \\ y_{i1} & \cdots & y_{ij} \end{pmatrix}$$

i<=m; j<=n-1

4. To the time difference matrix optimization iterations, it has been provided based on the current frequency of the current schedule under the title Timetable optimization algorithm.

5. Taking into account the running of public transport enterprises, we not only need to complete the social benefits of transportation, but also should consider the considerable economic benefits, cost savings, energy conservation. So it should be optimized to run on duty bus inspection schedules, inspection standards schedule period of time in which public transport vehicles load factor C_i, j, j +1 for the test.

To ensure safe operation and comfort, buses, load factor C_i, j, j +1 should be less than the specified value. Now we usually use the full rate, so that during peak hours should not exceed 1. If C_i, j, j +1> 1 situation, in order to ensure the quality of passenger travel and transit service levels, should consider the additional flights, the specific frequency of additional lines should be based on actual conditions and characteristics that:

C_i, j, j +1 <= 1

- --- C_i, j, j +1 is expressed as the matrix column vector sequence i, j and site lines at the site between the load factor j +1.

Meanwhile, for the protection of the economic benefits of public transport enterprises, while the location is too low to prevent buses caused by the utilization of waste transport capacity, personnel, fuel and other waste of energy resources, respond to public transportation vehicles loaded with an appropriate minimum standards set to protect bus efficiency and cost out of the bus. Usually considering C_i, j, j +1> 0.5 as measured by the standard bus, if the case load factor less than 0.5, it can be drawn vehicles to reduce the frequency of bus costs and public transportation resources to achieve savings.

In summary, the model schedule optimization objective function.

MIN Z=

$$\sum_{i=1}^{n}\left(\sum_{j=1}^{n}\left(\frac{\left(\sum_{j=1}^{n}(y_{ij})\right)}{j}-y_{ij}\right)^{2}\Bigg/ j\right)$$

s.t.:

$$\begin{cases} x_n \le s_n \\ \left(x_{n-1}+t_{1,n-1}\right)-\left(x_n+t_{1n}\right)\le d \\ c_{i,j,j+1}\le 1 \\ c_{i,j,j+1}\ge 0.5 \\ \forall n\in N, m\in M \end{cases}$$

Model operation flow chart shown below:

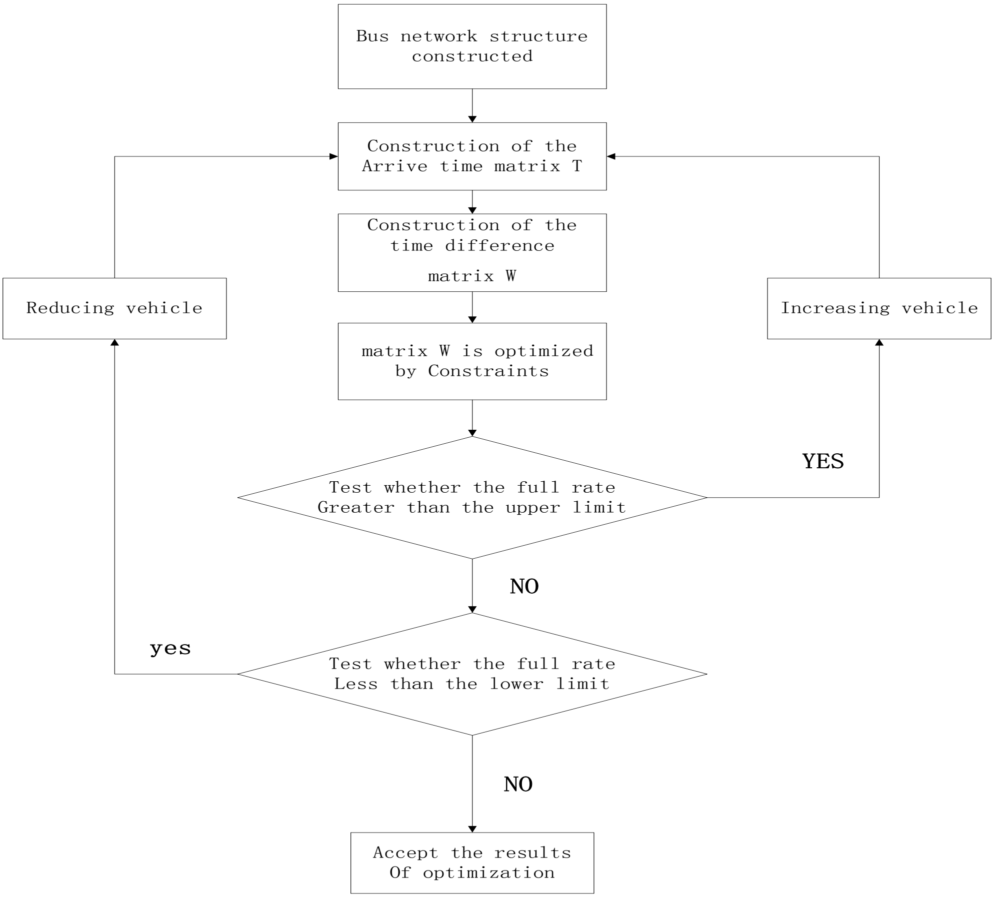

Figure 1: Model flow chart.

3.2. Algorithm

The main computation and algorithms is focusing on line site for the time difference between the optimized matrixes W, through W for the time difference matrix, to achieve the optimization objective function.

1. Part I: Determine the initialization matrix W
2. Part II: the next step iterative search direction and step size.

Calculate the time difference matrix Y_{ij} mean and variance of each row, select the largest variance to adjust the target line as the line step. Size data were taken with the data of the line itself, the mean difference of 1 / 2.

3. Part III: updated matrix to the second step to adjust the results as the base line, according to different frequencies, different lines in the travel time between different sites on the W matrix to adjust the time difference

4. Part IV: Calculate the objective function, by objective function value Z_i.

5. The convergence of the test results

Termination the test, when the $(Z_i\text{-}Z_{i-1})$ / Z_i <0.5, then accept the recognition result of convergence, if $(Z_i\text{-}Z_{i-1})$ / Z_i>0.5, the return to the second step, to continue the calculation until the results meet the convergence.

4. Number Example

To verify the algorithm validity, we selected BUS NO.910 and BUS NO.65 as an example. We select from the Nanpu Bridge Station to Shiliupu Station as the research section of the site.

Figure2: BUS NO. 65.

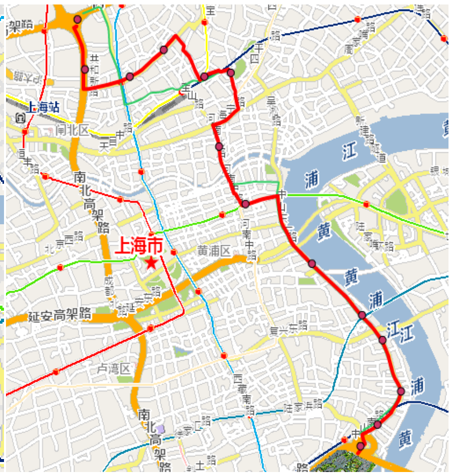

Figure3: BUS NO.910.

Table 1: The list of passenger arrival rate

	Station				
	Nanpu Bridge	Duojia Road	Dongjiadu	East Fuxing Road	Shiliupu
passenger arrival rate（person/min）	8	3	3	3	2

The establishment of the initial timetables based on the current schedule.

Table 2: The list of initial timetable

Station	Arrival time					
Nanpu Bridge	0	3	4	7	11	15
Duojia Road	1	5	5	9	13	16
Dongjiadu	3	7	7	11	15	18
East Fuxing ROAD	4	8	8	14	18	19
Shiliupu	5	9	9	15	19	20

According to the initial departure time and the travel time between different sites, we can get the time difference between sites form.

Table 3: The list of time difference of arrival of vehicles

Station	Time difference of arrival of vehicles					Expected value	Varian ce
Nanpu Bridge	3	1	3	4	4	3	2.4
Duojia Road	4	0	4	4	3	3	4.8
Dongjiadu	4	0	4	4	3	3	4.8
East Fuxing ROAD	4	0	6	4	1	3	9.6
Shiliupu	4	0	6	4	1	3	9.6
summary							31.2

using MATLAB7.1 as computational tools for programming calculation, given the selection of the biggest variance = 0.03 per step adjustments to the line with the new matrix, re-iterate, after 4 iterations to get convergence to meet the requirements matrix, optimized The time difference is as follow:

Table 4: The list of optimized time difference of arrival of vehicles

Station	Time difference of arrival of vehicles					Expe cted valu e	Variance
Nanpu Bridge	2	3	1	3	5	2.7	2.08
Duojia Road	3	2	2	3	3	2.6	0.48
Dongjiadu	3	2	4	3	3	3	0.8
East Fuxing ROAD	3	2	4	3	2	2.8	1.12
Shiliupu	3	2	4	3	2	2.8	1.12

Summary	5.6

Be adjusted time schedule grid:

Table 5: The list of optimized timetable

Station	Arrival time					
Nanpu Bridge	0	2	5	6	9	14
Duojia Road	1	4	6	8	11	15
Dongjiadu	3	6	8	10	13	17
East Fuxing ROAD	4	7	9	13	16	18
Shiliupu	5	8	10	14	17	19

Checking the average rate, the result is 0.63.So we receive optimal results without the need to adjust the number of flights.

From the above comparison table, we can see in the time period, according to different lines in different travel time between stations, for a total time of departure on the line segment using the model to optimize the waiting time difference between stations can significantly reduce the variance reduced from 31.2 to 5.6, that is, if the first class of vehicles through the Nanpu Bridge Station departure time of 8:00, then follow the vehicle should turn to 8:02, 8:05, 8:06, 8:09, 8:14 order, followed through, to the greatest extent in the total line of each bus running on the average vehicle arrival time smooth and orderly, in line with the concept of model design things, to avoid the emergence caused by the concentration of station waste of transport capacity and the emergence of traffic waiting line large interval of the situation, and the full rate of public transport vehicles to meet the upper and lower limits. Can better take into account the passengers had time to consider the social benefits of travel with the bus company ticket distribution for the average operating cost savings and social benefits.

In practice, the line attribute data and travel time characteristics of the different time periods due to passenger demand and traffic conditions vary, so duplication of data in accordance with the corresponding period of the model and solution methods can work out the bus all day Network departure timetable.

5. Conclusion

Conventional public transport operators are to determine the focus of scheduling the departure time of buses and departure intervals. The models mentioned in this article are based on the existing bus route schedule and its goals are to adjust bus arrival time difference. Using the number of passenger on the regional transit network as the adjusted basis to control the number buses on the lines to achieve a total line for the bus to run on the network segments of different lines, different vehicle departure time interval is optimized and adjusts to the grid. So the local public transport network could achieve the overall integration of resources, increasing efficiency. The purpose of the model basically, is not only feasible, but also benefits to making computer programming and automatic calculation of time.

Model of the basic functions can be achieved, but there are still many areas for improvement:

1. Present models used in bus travel time between sites is still the method based on historical data, summarized by the average, not the actual operation of the dynamic values, without considering and refining at different times in different sections of the possible cases resistance in the way most affected, and in the event of the possible impact of delays

2. The road network by the method and further research remains to be, how big a reasonable public transport network in the refinement of the different public transport sub-network, makes the model play a role in a wider context, people need to be explored

3. For a number of lines in different regions of the complex collinear prioritization need further data processing and model building

In response to these problems for further study and efforts to resolve the current inadequacies of the model, so that large areas can be able to verify and use of our goals and direction of future research.

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