International Journal of Hybrid Information Technology
Vol. 9, No.7 (2016), pp. 325-336
http://dx.doi.org/10.14257/ijhit.2016.9.7.29

Research on Multi-Vehicle Logistics Ridesharing Matching Problem with Space-Time

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Abstract

Multi-Vehicle logistics ridesharing matching problem has been the core issue in the field of logistics optimization. However, most studies focus on static issues, and the actual results need to improve. In this paper, firstly, the formalized description of multi-vehicle logistics ridesharing matching problem with space-time is offered, and a series of algorithms are studied, namely, the determination algorithm of virtual travel time of a section, the determination algorithm of the actual travel time of a section, as well as the determination algorithm of the number of periods spanning K + 1, the determination algorithm of the vehicle speed. Considering the impact that the environment change has on the vehicle path, this paper introduces the path reliability evaluation, and participants can make the path selection based on the actual needs and decision-making style. To verify the effectiveness of the algorithm, we construct a time-varying network and design the correlative experiments. We design the riding experiment of vehicle in different working days. Experimental results show that it works well, and can provide excellent options for the actual logistics ride.

***Keywords**: Logistics ridesharing matching problem; Vehicle route optimization; Space-time characteristics; Path reliability evaluation*

1. Introduction

Logistics matching problem, also known as ridesharing matching problem, is a deformation of the VRPSPD problem. Compared with VRPSPD[1] problem, it also has its own characteristics as follows: (1) vehicles in VRPSPD problem provide special transportation service and have no surplus capacity while vehicles from logistics matching problem would have to contribute their remaining capacity and meet their own needs first; (2) from the point of view of the optimization difficulty, the optimization difficulty of the logistics matching is greater. According to the different classification standards, logistics matching problem has many classification methods. From the point of the number of the participating ridesharing vehicles , it can be divided into single vehicle sharing problem and multi-vehicle sharing problem; from the time window constraint, it can be divided into ridesharing problem without time window constraint and ridesharing problem with time window constraint[2][3]. From demand of vehicle riding and heterogeneity of the vehicles, the problem is divided into homogeneous and heterogeneous ridesharing problem. From dynamics of the vehicle and vehicle riding demand, the problem is divided into static ridesharing problem and dynamic ridesharing problem [4]. From whether to allow the transfer of the vehicle, the ridesharing problem is divided into ridesharing problem which supports transfer of vehicles and problem which does not support transfer of vehicles. From vehicle attributes, it is divided into taxi ridesharing problem, private cars ridesharing problem and logistics ridesharing problem, *etc*[5-8]. From vehicle priority, it is divided into the problem which does not consider the

ISSN: 1738-9968 IJHIT

priority and which does[9][10][11].

In view of the current logistics field, especially the serious problem of vehicle vacancy phenomenon existing in the field of emergency logistics, on the basis of the SVLRMP problem [12], MVLRMP [13, 14] research results, this paper studies the multi-vehicle ridesharing matching problem with space-time characteristics of the road network (Multi-vehicle Logistics Ridesharing Matching Problem with Space-Time, referred to as the MVLRMP-ST problem) and constructs a mathematical model which supports the multi-vehicle ridesharing matching problem based on TSCA algorithm proposed in literature [13], and designs a path optimization TSCA-ST algorithm. Experimental results show that the vehicle riding path can be available effectively and has a certain practical value.

2. Description of the Problem and Characteristics of Time-Varying Network

2.1. Problem Description

MVLRMP-ST problems are described as follows: team F composed of M car in a region, which will be able to provide vehicle riding service on the basis of meeting its own travel needs. In the region there exists *n* demand of vehicle riding services. The model of the vehicle brand, the residual capacity and the speed of each are not identical. Assume that the whole travel information and the information of all the vehicle riding service demand in the team F is determined in advance and keeps unchanged, at the same time vehicle drivers, the pickup and delivery points are determined and correspond with the fixed service time windows. The sections in the research field are divided into sections of different types, the speed requirements of different sections varying, and the speed in the same section at different time also different; meanwhile, the vehicle speed and route selection will also be influenced by abnormal accident and weather conditions.

Without considering the difference of riding service demand and the selectivity of vehicles for the riding service demand, suppose:1) all the vehicles and vehicles in need of riding service can reach the specified car position within the specified time window; 2) when a vehicle gets to a pickup point earlier than the window lower bound of the business hours, it needs to wait for the lower bound to the time window, and leaves at the same time; 3) in the team, there is at least one vehicle satisfying the maximum capacity requirements of riding demand, and the sum of the vehicles of all the riding demand service is not more than the team remaining capacity; 4)the space-time characteristics of the section has an important effect on the speed of the vehicle, the speed of the vehicle varying in different time of a section, however, in a certain period the vehicle runs at an average speed; 5) leave out the vehicle business hours of riding service demand, namely, leaving out the hours it takes to get on or off; 6) leave out the effect of traffic lights at the intersection on the vehicle driving speed; 7) without considering the vehicle transfer, that is to say, there is at most a car service received in a ride service demand.

The goal of the problem is to reduce the team overall average running cost on condition that the successful rate of vehicle riding is raised as much as possible. Considering the space-time characteristics of the road network, raising the success rate of vehicle riding is the most important in the complex external environment; only on the basis of the above does it make sense in practice when reducing the team overall average running cost is considered.

2.2. Time Varying Network

The path optimization based on a time-varying road network, is the research hot spot in recent years [15, 16, 17]. The research on this aspect is divided into two types: the time-varying network research based on the real-time data [18, 19, and 20] and the time-varying network research based on the historical data [21]. In the traffic road network, if two intersection points (such as nodes *i*, *j*) of the network are directly connected to an edge, then the edge (*i*,*j*) is called a section. The inherent characteristics of the section include road width, the number of the lanes, road types, speed limit characteristics, *etc*. For example, according to road types, it can be divided into expressway, national and provincial highway, urban roads, urban general road, *etc*. Another example is the speed limit characteristics of the section. The speed limit of a highway section is 90-120 km / h, *etc*. In a time-varying network, influenced by the change of the traffic flow and abnormal situations, besides the inherent characteristics, there exist other more space-time characteristics for a section [22].

First, discuss the time characteristics of the section. For the same road, due to the different traffic flows in different period, the vehicle speed will change. For example, in the usual weekdays (from Monday to Friday), public commuting time is a key factor to affect the [23] traffic.

3. MVLRMP-ST Problem Model

3.1. Problem Formulation

First define the time-varying network of the problem, and ***G_td***= (***V, E, W, T, En***), (*V* is the set of all nodes in the network; *E* is the set of edges(sections) in the network, and the edge $(i, j) \in E$ represents the section from node *i* to node *j*; *W* is the collection of weighting function of edge set E in the section on time $[t_0, t_m]$, the elements $\omega_{ij}(t)$ denoting the weight of the edge (i, j) in t moment, weight can be road length, also can be the vehicle travel time in the time-varying state in the section, and can also include the road length, travel time and the vector of other factors. *T* denotes the time interval $[t_0, t_m]$, *En* as a collection of environmental characteristics of the network, $En = \{en_{ij} \mid (i, j) \in E\}$, environmental characteristics of the section $en_{ij} = (en_{ij}^{mon} \mid 0 < en_{ij}^{mon} < 1, mon = 1,2,...12)$ is a vector containing 12 elements, denoting the traffic capacity of $(i, j) \in E$ in the 12 months of the year, the larger the value, the stronger the traffic capacity.

According to research needs, discretize the time interval and define Δt as a small period of time, then *T* can be discretized into $\{t_0, t_0 + \Delta t, t_0 + 2\Delta t, ..., t_0 + k \cdot \Delta t, ..., t_m\}$ (k is a positive integer) and let $S = \{t_0, t_0 + \Delta t, t_0 + 2\Delta t, ..., t_0 + k \cdot \Delta t, ..., t_m\}$. Based on the definition of T, without loss of generality, for a vehicle, we assume that the vehicle speed keeps unchanged in the short time interval.

On the basis of above, G_td is redefined as ***G_td*=(*V, E, W, S, En*)**, where the weight function set ***W*** is defined as $W = \{\omega_{ij}(t) \mid t \in S\}$. For $\omega_{ij}(t) \in W$, there is

$$\omega_{ij}(t) = (d_{ij}, t_{ij}(t)) \tag{1}$$

In (1), $\omega_{ij}(t)$ is a vector, d_{ij} denotes the length of section (i, j), and $t_{ij}(t)$ denotes the time the vehicle takes to reach the node *i* at time *t* after passing the edge (i, j) by. In a static network, $t_{ij}(t)$ can be obtained by the road section length d_{ij} divided by the vehicle speed. However, in a time-varying network, due to the traffic flow information of different periods and sections varying, the vehicle speed is not uniform when it is through the section. Therefore, the calculation of $t_{ij}(t)$ becomes more complicated.

3.2. The Relaxation of Time Window Constraint

In time-varying network, changing the hard time window constraint into the soft time window constraint can be considered. Define Δt_{relax} as the tolerate relaxation time of all the service requirements; the time window $[e_x, l_x]$ of a node x can be changed into $[e_x - \Delta t_{relax}, l_x + \Delta t_{relax}]$. If the riding activities meet a new time window, a certain punishment can be given based on the advanced or delayed time.

4. Key Factor of TSCA-ST Algorithm

The TSCA algorithm [13] can effectively solve the problem of logistics riding matching problem based on the static network. In a time-varying network, due to the speed characteristics of different sections different, the speed characteristics of different vehicle is not the same. TSCA-ST (Two-stage Clustering Algorithm with Space-Time) is a new algorithm which can be used to solve the MVLRMP-ST problem.

4.1. Determination of Time Which Takes to Cross the Section

In ***G_td***, the route between any two nodes can be described as:

$$Path_{ij} = \{(v_i, t_i), (v_1, t_1), (v_2, t_2), ..., (v_j, t_j)\} \qquad (2)$$

In (2), v_i, v_1, v_2,... v_j, composed of a feasible path from node v_i to the v_j, namely $v_i \to v_1 \to v_2 \to ... \to v_j$, t_i, t_1, ..., t_j, as the moment the vehicle reaches/departs each node. To calculate the time spent on a section, calculating the time spent on each section is the key to solve the problem. In a time-varying network because of the influence of commuting, holidays and abnormal situation, the time spent on a section is uncertain, therefore it is the issues of TDTSP (Time-depended Traveling Salesman Problem) [24,25] on which the scholars have done more research on this respect. The time-varying characteristics of the network structure has been a research hot spot, there being literature [26,27] using step function to represent the time dependence. In determination of the speed in the section *(i, j)*, the speed at which the vehicle reaches the point I is used, which is clearly an approximation with the actual problem, and there is an jump phenomenon for the running time when it spans the period, which is not realistic and does not satisfy the **FIFO** guidelines [24] [28]. In this paper, we learn and improve the method of processing time in the section of spanning the period proposed by literature [29].

4.1.1. Virtual Driving Time of Sections

Assuming 24 hours a day is divided into P sections, defining $[B_p, B_{p+1}]$ as a time interval (period), $p = 1,2, ..., P, P+1$, the length of each time period determined by the characteristics of the network traffic flow. Suppose the time required for the vehicle via the section *(i, j)* as t_{ij}, and in the process of passing through the section it needs to span $K + 1$ periods, the length of the section d_{ij} divided into $K + 1$ parts by the whole period, denoted as $d_{ij}^1, d_{ij}^2, ..., d_{ij}^k, ..., d_{ij}^K, d_{ij}^{K+1}$. Assume a vehicle in the period k can finish the entire road d_{ij}, and the traveling speed of the vehicle is vel_k, then the time to finish the whole journey is:

$$t_{ij}^k = \frac{d_{ij}}{vel_k}, k = 1,2,..., K+1 \qquad (3)$$

Obviously t_{ij}^k is not the actual time required for the vehicle through the sections (i, j) but the virtual time, and we will use the time back. When the vehicle does not span time, calculating the time required for a section is very simple, and then it is precise to use the road length divided by the speed of the period.

4.1.2. Actual Travel Time of Sections

First consider the case that the vehicle reaches the node 1 in the period i, travels in the section (i, j) and does not span the period 1. Under this case, there is no change in the vehicle speed and the travel distance is d_{ij}, then the travel time of the vehicle to the node j is

$$t_j = t_i + t_{ij}^1 = t_i + \frac{d_{ij}}{vel_1} \tag{4}$$

By (3), the actual time passing through section (i, j) is:

$$t_{ij} = \sum_{k=1}^{K+1} \frac{d_{ij}^k}{d_{ij}} \cdot t_{ij}^k \tag{5}$$

Specifically, assume that the vehicle starts from node i from time t_i, without loss of generality, assuming $t_i \in [B_1, B_2]$, then the time length required for the vehicle traveling through the road d_{ij}^1 at the first time interval is $B_2 - t_i$. Define the time spent on the road as rt_{ij}^k when traveling on the section, then

$$rt_{ij}^1 = B_2 - t_i, \quad d_{ij}^1 = d_{ij} \cdot \frac{rt_{ij}^1}{t_{ij}^1} = d_{ij} \cdot \frac{B_2 - t_i}{t_{ij}^1} \quad \ldots$$

$$rt_{ij}^k = B_{k+1} - B_k, \quad d_{ij}^k = d_{ij} \cdot \frac{rt_{ij}^k}{t_{ij}^k} = d_{ij} \cdot \frac{B_{k+1} - B_k}{t_{ij}^k},$$

$$d_{ij}^{K+1} = d_{ij} - \sum_{k=1}^{K} d_{ij}^k \tag{6}$$

By (6), the time required for the vehicle to complete the road d_{ij}^{K+1} at the $K + 1$ moment is

$$\begin{aligned} rt_{ij}^{K+1} &= \frac{d_{ij}^{K+1}}{d_{ij}} \cdot t_{ij}^{K+1} = \frac{1}{d_{ij}}(d_{ij} - d_{ij} \cdot \frac{B_2 - t_i}{t_{ij}^1} - d_{ij}\sum_{k=2}^{K} \frac{B_{k+1} - B_k}{t_{ij}^k}) \cdot t_{ij}^{K+1} \\ &= (1 - \frac{B_2 - t_i}{t_{ij}^1} - \sum_{k=2}^{K} \frac{B_{k+1} - B_k}{t_{ij}^k}) \cdot t_{ij}^{K+1} \end{aligned} \tag{7}$$

The total time of the vehicle traveling in section (i, j) is

$$\begin{aligned} t_{ij} &= \sum_{k=1}^{K+1} rt_{ij}^k = rt_{ij}^1 + \sum_{k=2}^{K} rt_{ij}^k + rt_{ij}^{K+1} \\ &= (B_2 - t_i) + \sum_{k=2}^{K}(B_{k+1} - B_k) + (1 - \frac{B_2 - t_i}{t_{ij}^1} - \sum_{k=2}^{K} \frac{B_{k+1} - B_k}{t_{ij}^k}) \cdot t_{ij}^{K+1} \\ &= B_{K+1} - t_i + (1 - \frac{B_2 - t_i}{t_{ij}^1} - \sum_{k=2}^{K} \frac{B_{k+1} - B_k}{t_{ij}^k}) \cdot t_{ij}^{K+1} \end{aligned} \tag{8}$$

Thus after calculating, the time of the vehicle reaching node j is

$$t_j = t_i + t_{ij} = B_{K+1} + (1 - \frac{B_2 - t_i}{t_{ij}^1} - \sum_{k=2}^{K} \frac{B_{k+1} - B_k}{t_{ij}^k}) \cdot t_{ij}^{K+1} \tag{9}$$

Based on (9), we obtain the relationship between t_i, t_j

$$\begin{aligned} t_j &= \frac{t_{ij}^{K+1}}{t_{ij}^1} \cdot t_i + B_{K+1} + (1 - \frac{B_2}{t_{ij}^1} - \sum_{k=2}^{K} \frac{B_{k+1} - B_k}{t_{ij}^k}) \cdot t_{ij}^{K+1} \\ &= \frac{vel_1}{vel_{K+1}} \cdot t_i + [B_{K+1} + (d_{ij} - B_2 \cdot vel_1 - \sum_{k=2}^{K}(B_{k+1} - B_k) \cdot vel_k) \cdot \frac{1}{vel_{K+1}}] \end{aligned} \tag{10}$$

Let

$A' = \dfrac{vel_1}{vel_{K+1}}$, and $B' = B_{K+1} + (d_{ij} - B_2 \cdot vel_1 - \sum_{k=2}^{K}(B_{k+1} - B_k)\cdot vel_k)\cdot \dfrac{1}{vel_{K+1}}$, A' 、 B' are known constants, then equation (10) can be deformed into

$$t_j = A't_i + B' \tag{11}$$

Obviously t_j is the incremental function of t_i. If the vehicle only spans a period that $K = 1$, there is

$$d_{ij}^1 = d_{ij}\cdot\frac{B_2 - t_i}{t_{ij}^1},\quad rt_{ij}^1 = B_2 - t_i$$

$$d_{ij}^{K+1} = d_{ij}^2 = d_{ij} - d_{ij}^1 = di_j(1 - \frac{B_2 - t_i}{t_{ij}^1})$$

The time required for the vehicle traveling in the section (i, j) after spanning the first period is

$$rt_{ij}^{K+1} = rt_{ij}^2 = \frac{d_{ij}^2}{d_{ij}}\cdot t_{ij}^2 = \frac{1}{d_{ij}}(d_{ij} - d_{ij}\cdot\frac{B_2 - t_i}{t_{ij}^1})\cdot t_{ij}^2$$
$$= (1 - \frac{B_2 - t_i}{t_{ij}^1})\cdot t_{ij}^2$$

Finally, the time the vehicle reaches the node j is

$$\begin{aligned} t_j &= t_i + t_{ij} = t_i + [rt_{ij}^1 + rt_{ij}^2] \\ &= t_i + [(B_2 - t_i) + (1 - \frac{B_2 - t_i}{t_{ij}^1})\cdot t_{ij}^2 \\ &= \frac{vel_1}{vel_2}\cdot t_i + (d_{ij} - B_2\cdot vel_1 + B_2\cdot vel_2)\cdot\frac{1}{vel_2} \end{aligned} \tag{12}$$

Let $A'' = \dfrac{vel_1}{vel_2}$, and $B'' = (d_{ij} - B_2\cdot vel_1 + B_2\cdot vel_2)\cdot\dfrac{1}{vel_2}$, formula (12) is deformed into

$$t_j = A''t_i + B'' \tag{13}$$

Formula (11) and (13) have the same form and are consistent with the actual situation. The question now is how to determine the number of periods $K+1$ that the vehicle spans when traveling on the road.

4.1.3. Determination of K

Analyzing (10), to calculate the time t_j when the vehicle reaches the node j, the number of periods $K + 1$ that the vehicle spans when traveling on the road ought to be clear. Figure 1 below is used to describe it.

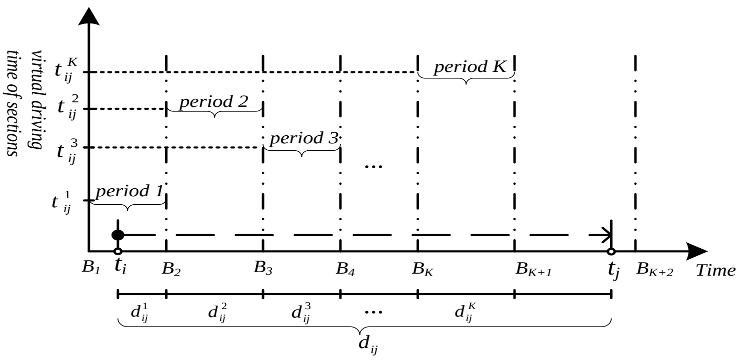

Figure 1. Schematic of Vehicles Spanning Multiple Periods

The vehicle starts from node I to reach node j at time t_i in the process, after a period of a sequence, period 1,2, ..., K still not arrives at the node j. Assume in period $K + 1$ the vehicle reaches the node j, then the vehicle has spanned the $K + 1$ periods, where the period 1, period $K + 1$ belongs to the period in which the vehicle does not completely travel, while the period 2, period3, ..., K belongs to the period when the vehicle has a complete travel. To make the vehicle starts from the period 1 to K sequentially, and finish with the whole road in the $K + 1$ within a certain period, the following conditions must be met:

Condition 1: the time of the vehicle departing from node I must be in the period 1, there is,

$$B_1 < t_i < B_2 \tag{14}$$

Condition 2: the vehicle does not complete the whole road when leaving in the period K, but in period $K + 1$ the vehicle must complete the whole road, there is,

$$\begin{aligned} & d_{ij}^1 + d_{ij}^2 + ... + d_{ij}^K \le d_{ij} \\ & \quad < d_{ij}^1 + d_{ij}^2 + ... + d_{ij}^K + (B_{K+2} - B_{K+1}) \cdot vel_{K+1} \end{aligned} \tag{15}$$

And we have

$$\begin{aligned} & B_2 + (\sum_{k=2}^{K} (B_{k+1} - B_k) \cdot \frac{vel_k}{vel_1} - \frac{d_{ij}}{vel_1}) \le t_i \\ & \quad < B_2 + (\sum_{k=2}^{K+1} (B_{k+1} - B_k) \cdot \frac{vel_k}{vel_1} - \frac{d_{ij}}{vel_1})) \end{aligned} \tag{16}$$

We regard K in (16) as the variables. As long as the value of K can be determined, the time of the vehicle reaching the node j can be calculated. Use the following steps to calculate the value of K: (1) on the basis of the average speed, calculate the time from the node i to node j, denoted as ft_{ij}; (2) judge that the time t_i+ft_{ij} falls within which period, assuming it falls on the K' period; (3) take the $K = K'$ into the (16), and determine whether the condition is satisfied. If it is satisfied, then let $K = K'$; otherwise let $Kl = K'-1$, $K_r = K'+ 1$. At the same time keep trying to the left and right period until you find the first qualifying K_l or K_r.

4.2. Determination of Vehicle Speed

By analyzing (10) and (16), we can find that vehicle speed is of vital importance in the whole solving process. Vehicles can be roughly divided into three types from actual situation: Ⅰ, Ⅱ and Ⅲ, respectively corresponding with slow, medium and high speed vehicles. The same type of vehicles drives according to the same speed rules. Suppose that a vehicle starts from node i at t_i and will reach node j through side (i,j). Define the vehicle' s daily range of speed as $[v^l, v^h]$, speed limit of road section (i,j) as $[v_{ij}^l, v_{ij}^h]$ and average speed at k time frame as v_k, then confirm the vehicle' s speed vel_k when running on one section and crossing time frame according to the following steps: (1) decide type of the date according to departure date of the vehicle and then inquire from historical traffic flow database about traffic flow information of that day and later days to ensure enough number of time frames; (2) determine value of K;(3) determine historical average speeds $v_1, v_{2,...,} v_K, v_{K+1}$ from time frame 1 to $K+1$;(4) for any time frame k, there is

$$vel_k = \begin{cases} \min(v_{ij}^h, v^h) & , \ k \text{ belongs to low peak of } flo\text{\textbackslash} \\ v_k & , \ other \end{cases} \tag{17}$$

In (17), v_j is replaced by vehicles' average speed in time-varying network. To distinguish, define $\overline{vel}_j$ as vehicles' average speed in time-varying network, and then there is $RSv_x^j = RTv_x^j \cdot \overline{vel}_j$.

5. Numerical Experiment and Result Analysis

5.1. Fundamental Data of the Experiment

We design 185 carpooling service requirements and 50 cars. In addition to the above fundamental data, feature information of sections in the road network mainly include: 1) section location and speed information; 2) temporal characteristics of the section, mainly are time frames of low traffic flow cycle, flat hump and high flow cycle set according to workdays and holidays based on the section's own characteristics; 3) environmental characteristics information. Information on section speeds and environmental characteristics are all obtained through historical data statistics and references [18].

5.2. Experimental Process and Analysis

Based on fundamental data of the experiment, change the date while keep the time fixed, and average all conclusions after continuously conducting the experiment for 100 times, the results are as follows.

No.	Characteristics of date	Success rate of carpooling (%) (hard /soft time window)	average running time(s)	average speed (km/h)
1	workday	75.64 82.24	1972.81	85.16
2	holiday	64.81 * 78.42	2014.19	54.72
3	mix date	64.75 * 81.09	2006.71	61.91

Table 1. Comparison of Optimization Results on Different Departure Dates

Through Table 1 we conclude that since traffic flow changes at a high frequency during holidays, there are more time frame switches and it takes the algorithm more time to run. Average speed of vehicles is slower and success rate of carpooling is also affected (the rate is only 64.81% when not changing time window constraint; it increases to 78.42% when slacking time window constraint). Moreover, when going out on mix date, its algorithm characteristics are similar to that of holidays, but average speed is higher.

According to previous years' statistic laws, speed characteristic of the studied highway sections on workdays is that there is a time frame every 30 minutes, altogether 48 in a day. Suppose that speeds of vehicles stay the same during the same time frame: it is low cycle of traffic flow before 9:30 am and vehicle speed can reach 110km/h; it is flat hump from 9:30 am to 16:00 pm and vehicle speed reduces to 80km/h; it is low cycle after 16:00 pm and vehicle speed restores to 110km/h. While on workdays of national or provincial road sections, speed characteristics are different affected by rush hours: it is low cycle of traffic flow before 6:30 am and vehicle speed is 60km/h; it is high cycle from 6:30 am to 9:30 am (morning peak) and vehicle speed reduces to 30km/h; it is flat hump from 9:30 am to 16:30 pm and vehicle speed increases to 50km/h; it is high cycle again from 16:30 pm to 19:30 pm (evening peak) and vehicle speed falls back to 30km/h; it is low cycle after 19:30 pm and vehicle speed restores to 60km/h, just as shown in Table 2. The above speeds are average ones and of different types of vehicles, actual speeds passing different road sections at different time frames will also be different.

Figure 2. illustrates the speed change situation when vehicles drive along some route. On workdays the vehicle starts from departure point and passes national and provincial roads, highway and national and provincial roads again before reaching the termination. At first it goes through low and high cycles of the national and provincial roads with speed reducing from 60km/h to 30km/h; then it drives into highway with speed increasing to 110km/h and then reducing to 80km/h; after getting off the highway, its speed falls back to 50km/h. vehicle’ s average speed is about 70km/h. Polynomial trend line can gradually approach actual running speed of the vehicle. When vehicles drive along the same route on other workdays, speed at some moment can be estimated by referring to this trend line. After that we can figure out when the vehicle will arrive at some node.

<table>
<tr><td>Highway sections</td><td colspan="6">low cycle （high：110km/h）</td><td colspan="3">Flat hump （medium：80 km/h）</td><td colspan="7">low cycle （high：110 km/h）</td></tr>
<tr><td>National and provincial sections</td><td colspan="3">low cycle （high：60 km/h）</td><td colspan="2">High cycle （low: 30 km/h）</td><td colspan="5">Flat hump （medium：50 km/h）</td><td colspan="3">High cycle （low: 30 km/h）</td><td colspan="3">low cycle （high: 60 km/h）</td></tr>
<tr><td></td><td>0:00</td><td>0:30</td><td>6:30</td><td>7:00</td><td>9:00</td><td>9:30</td><td>10:00</td><td>15:30</td><td>16:00</td><td>16:30</td><td>17:00</td><td>19:00</td><td>19:30</td><td>20:00</td><td>23:30</td><td>0:00</td></tr>
<tr><td>Time frame</td><td>0</td><td>1</td><td>13</td><td>14</td><td>18</td><td>19</td><td>20</td><td>31</td><td>32</td><td>33</td><td>34</td><td>38</td><td>39</td><td>40</td><td>47</td><td>48</td></tr>
</table>

Table 2. Traffic Flow and Speed Characteristics of Time-Varying Road Network on Workdays

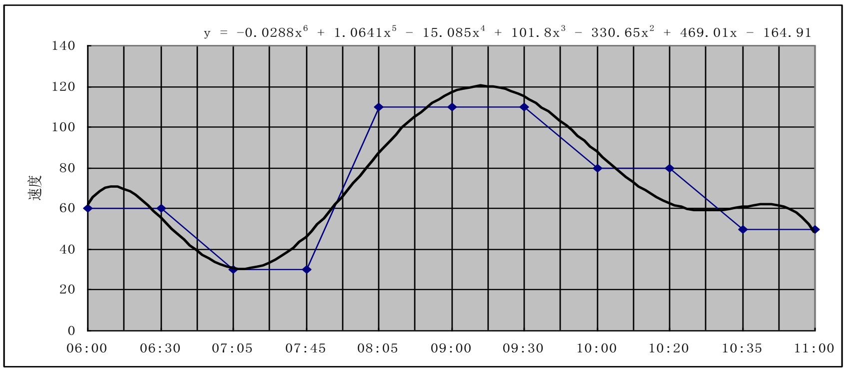

Figure 2. Vehicle Speed Characteristics on Workdays

6. Conclusions

In this paper, study is conducted on the logistics vehicle carpooling matching problem in time-varying network environment. First of all, the MVLRMP - ST problem is formalized, and constraints in time-varying network environment are modified. By referring to existing research results, detailed analysis and algorithm design are conducted on the section’ s virtual and actual driving time, confirmation of number of spanned time frames *K+1*, vehicle speeds *etc*. At the same time, to fully consider the effect of environmental change on vehicle’ s driving routes, this paper introduces the route reliability evaluation index, and carpooling participants can choose excellent vehicle routes according to actual needs and their own decision-making style. In order to verify the validity of the algorithm, we construct the time-varying network and design relevant experiments. In the experiment, both the vehicle type and section characteristics are heterogeneous, and also the reliability impact of environmental change on vehicle routes is considered. We design carpooling experiments on different types of workdays, and the experimental effect is good, which can provide alternative schemes for actual logistics carpooling and has certain practical value.

Although this study differentiates the capacity, speed and maximum carrying capacity of the vehicle and distinguishes the priority of service requirements, demands of vehicles on service requirements, options of the service requirements for vehicle conditions, and time needed by the service requirements can all be different. At the same time, in the long run, motion trails of the vehicles and the service requirements have certain regularity, which isn' t taken into account in this study. That will be our later research direction.

Acknowledgements

This work was supported by the National Natural Science Foundation of China under NO. 61272094, the Development of Science and Technology project of Shandong Province of China under No. 2014GGH201022, 2011YD01100.

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