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L. A. Panik

ABOUT DYNAMIC CASE HETEROGENEOUS TRANSPORT NETWORKS FRAMES

This article gives an analysis of the dynamic traffic when the units have an individual features (heterogeneity), and also takes into account the interaction of railway and motor transport networks.

Keywords: dynamic traffic current, heterogeneous traffic current, transshipments.

Introduction

The problem of finding the maximum traffic streams in networks is one of the fundamental in graph theory and combinatorial optimization. It has been studying for many years, due to its wide use in many practical applications related to the analysis of transport systems, material flow systems, computing and communication networks, energy, etc. [1, 2].

As a rule, these applications are considered just single-unit streams without taking into consideration the individual features of units (heterogeneity) and the dynamic nature of streams. Accounting an individual characteristics and time is even more important while planning the transport stream in heterogeneous networks. The aim of this article is an investigation of mentioned above specific transport stream features.

Modeling the process of management traffic currents

Nowadays the management of traffic heterogeneous streams is an important logistics task. Due to this, traditionally in the references [1,2] several basic statements the problems of streams in networks are considered, where the heterogeneity of elements are taken. First of all, it is a single-united (when the stream in the arcs corresponds to some homogeneous unit), they include a standard transport problem, a mathematical model which is:

$$\min Z=\sum_i \sum_j c_{ij} x_{ij}$$

if

$$\sum_j x_{ij}=a_i,\, i=1,\dots m,$$

$$\sum_i x_{ij}=b_j\, j=1,\dots n,$$

$$x_{ij}\geq 0, i=1,\dots m,\, j=1.\dots n.$$

As well as multi-unit models of streaming tasks that are summarized by means of carriage problems [1,2]. These tasks do not include two more important aspects: the dynamic nature of streams, and the process of streams interaction (several kinds of transport). The tasks mentioned above are stationary. They are not taken into account the time for replacement of streams, from point i to another point j.

Both demand and supply for transporting depend on the time, as well as the traffic capacity, etc. However, the consideration of the time factor is very important. For instance, if perishables are carried, or if there is no means of communication between several traffic items at certain times. Because of these factors the traffic stream management must be discovered in dynamics (creating the models depending on time).

The dynamic problem about the interaction between different kinds of transport

The process of planning passenger transfers, from one vehicle to another, in transport networks is complicated by the uneven passenger flow through time and space. To accomplish this the research of railway stations infrastructure, bus stations, airports, etc., is needed in conditions of different passenger flow.

While planning, the transfer station for passengers flow from one vehicle to another must be identified. There the arrival and departure times should be redistributed in timetable. Mathematically, there arises the problem of optimizing the distribution of flows in multi-unit networks [3]. At the same time here is proposed the generalized model of planning the transfer, which takes into account the heterogeneity of the process according to requirements of passengers.

Taking into consideration the requirements of passengers, their heterogeneity, the content and complexity of the planning tasks become more complicated. In these cases, the models which include the individual features of the elements may appear [4,5]. The essence of realization the passenger requirements is in registration the categories of them (different kinds of transport).

Solution of optimization problems, including individual characteristics, is made with the help of the reduction method - by increasing the amount of state planning model.

Dealing with a mathematical model of dynamic current problem with transfers. There is a transport network as a directed graph $G(E, A)$. The rate of intensity of the traffic stream, is time-dependent, for each kind of transport k, for each $r-$of that direction, which is sent from the source s^r to the drain t^r, is known $f^{rk}(t)$.

Denote through $x_{ij}^{rk}(t)$ - the stream in an arc that corresponds to the number of passengers traveling directly from point i to point j, r -direction in k kind of transport, and in t time period, also $c_{ij}^{rk}(t)$ - is the cost of transportation the unit of stream (passenger from point i to point j *is*, time-dependent, for r direction and k - kind of transport, which includes the cost of transplant for some stream items. Then the mathematical model of planning with the regard to heterogeneity of stream will be as follows:

$$\sum_t \sum_r \sum_k \sum_i \sum_j c_{ij}^{rk}(t) x_{ij}^{rk}(t) \to \min \tag{1}$$

if limitations are:

$$\sum_k \sum_j x_{ij}^{rk}(t) - \sum_k \sum_j x_{ji}^{rk}(t) = -f^{rk}(t), i \in s^r, r = 1,2,\ldots R, t = 1,2,\ldots \tag{2}$$

$$\sum_k \sum_j x_{ij}^{rk}(t) - \sum_j x_{ji}^{rk}(t) = 0, i \notin E_S, j \notin E_l, r = 1,2,\ldots R, t = 1,2,\ldots \tag{3}$$

$$\sum_k \sum_j x_{ji}^{rk}(t) - \sum_k \sum_j x_{ij}^{rk}(t) = f^{rk}(t), i \in l^r, r = 1,2,\ldots R, t = 1,2,\ldots \tag{4}$$

$$0 \le \sum_r x_{ij}^{rk}(t) \le U_{ij}^k(t), (i,j) \in A, k = 1,2,\ldots K, t = 1,2,\ldots. \tag{5}$$

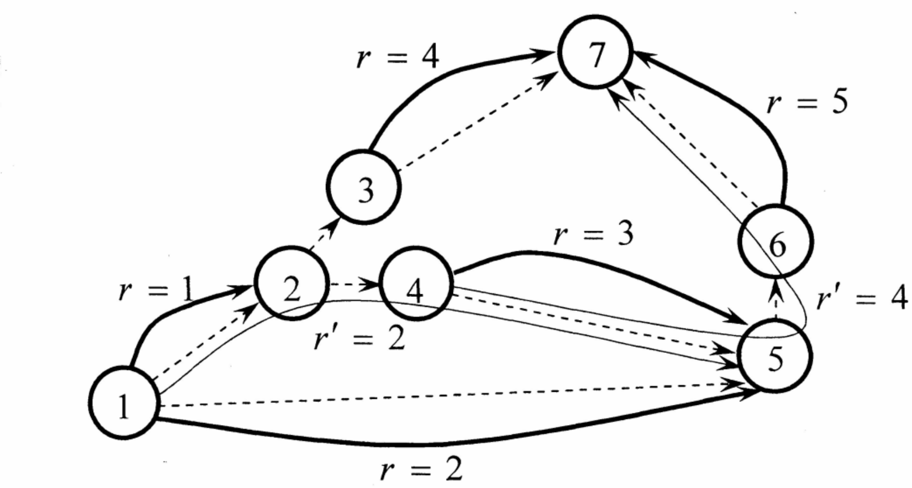
In this model $U_{ij}^k(t)$, this is the capacity of arc otherwise that is the number of seats in a passenger transport, which are sent from point i to point j in k kind of transport in the t period of time.

In this very model, unlike the model described in [5] a parameter t has appeared, which in this case indicates the moments of time (hours, days of the week, etc.). Because of this, that problem can be described as a problem of transportation planning.

Also in this model the characteristic r may depend on time, so that the directions may vary depending on time (closed traffic areas, the appearance of new ways in summer periods, etc.). If this model will contain the needed to travel from point i to point j, it can be considered as a multi-criteria the second criteria in which will be - the minimum time of traveling.

An implementation of dynamic streaming problem with transfers

It is considered the transport network with the graph in fig. 1, where r - the directions of passengers movement who needs to travel by two kinds of transport: trains, buses.



intended r passenger flow
alternatives of $r-$ passenger flow movement
second graph.
Figure 1. The logical graph of transport networks.

For each arc of the graph the capacity of each kind of transport known:

The capacity U_{ij} of arcs X_{ij} according to the transport kinds							
	X_{12}	X_{15}	X_{24}	X_{37}	X_{45}	X_{56}	X_{67}
Train	1	4	7	3	7	7	8
Bus	3	3	7	3	6	6	8

The fare taken from a single element of the flow (passenger) is also known, as well as the intensity of passenger flow

The fare C_{ij} a single element of the flow on arcs X_{ij}							
	X_{12}	X_{15}	X_{24}	X_{37}	X_{45}	X_{56}	X_{67}
Train	100	130	50	120	110	60	70
Bus	50	34	36	78	80	30	55

To solve the problem the methods of linear programming were used, after being redacted. As a result, the following characteristics were obtained:

Passenger flows according to direction (train)						
X_{12}	X_{12}-X_{24}-X_{45}	X_{15}	X_{45}	X_{37}	X_{45}-X_{56}-X_{67}	X_{67}
0	0	0	0	0	0	0

Passenger flows according to direction (bus)						
X_{12}	X_{12}-X_{24}-X_{45}	X_{15}	X_{45}	X_{37}	X_{45}-X_{56}-X_{67}	X_{67}
3	0	4	1	2	2	3

Solution of the problem is found by means of the reduction method [4, 5]. The total minimum cost of transportation the passengers of different categories is: 1017 USD. The results show that there was a division of passengers flow into several categories. This is because the fare of travel by bus is cheaper. That is why the motor transport was used for all direction.

The case where the direction *r*=2 (part of the way from point 1 to point 5 network graph in Fig. 1) there is no motor transport, and the capacity of the arc X_{15} is 2. The solution of the problem is as follows:

Passenger flows according to direction (train)						
X_{12}	X_{12}-X_{24}-X_{45}	X_{15}	X_{45}	X_{37}	X_{45}-X_{56}-X_{67}	X_{67}
0	1	2	0	0	0	0

Passenger flows according to direction (bus)						
X_{12}	X_{12}-X_{24}-X_{45}	X_{15}	X_{45}	X_{37}	X_{45}-X_{56}-X_{67}	X_{67}
3	1	0	1	2	2	3

The total minimum cost of transportation the passengers of different categories is: 1523 USD The comparison of results shows that the dynamic changes of the network characteristics leads to a changes in the distribution of passenger flows and kinds of transport.

The results of dynamic passengers flow planning including transfers on different kinds of transport shown according to the model (1) - (5), taking into consideration the capacity limitations for different kinds of transport. It is conceivable to divide the passenger flow because there are several categories of passengers. On the basis of calculations it become possible to plan the routes of inhomogeneous flows depending on the parameters of transport systems.

Conclusions

It is evident that the problem of optimization of dynamic heterogeneous flows generalizes all distinguished planning approaches. In this article the improved model of dynamic planning the trips with transferring from one kind of transport (train) to another (buses) is proposed. The processes of reduction allow to apply the methods of linear programming for effective numerical implementation of dynamic tasks in heterogeneous transport networks.

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