COMPUTER MODEL FOR OPTIMIZING PUBLIC TRANSPORT NETWORKS AND LINE SYSTEMS

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Abstract

The article shows a model which lends itself to evaluate changes in both public transport network and management. The superposition model comprises:

a) a network superposition model

b) a line superposition model

The effect of developments affecting the public transports of Csepel district relying on the computer model will be presented as an example.

In conclusion, the computer model is seen to lend itself to evaluate modifications of the network and of the line system, as well as to rate any measure of organization or management affecting the travel time and speed.

The method can be applied both in design and operation.

The spatial-timely system of urban public transport networks complete with lines, is based on the spatial-timely distribution of transport demands. Alteration of transport demands requires modification of the line system or the network. Evaluation of the existing system in functioning, according to different criteria, is imperative, but system characteristics should be known as soon as design work starts. Thereby the effect of intended modifications can be known and evaluated, in time several alternatives may be confronted and the one best meeting the given optimum criterion adopted still before realization.

The public transport systems are of magnitudes and complexities suitable to simulation via computer programs. The models lend themselves to evaluate changes in both public transport networks and management. With some neglection, models attempt to simulate the process of public transport, permitting model analysis of the effect and outcome of each input parameter.

The computer model presented for public transport network and line design is a superposition model of two parts, lending itself to evaluate the effect of modifications in the organization and management of public transport operation from the aspects of both passengers and operators.

The superposition model comprises:

a) a network superposition model;

b) a line superposition model.

a) *Network superposition model*

Input data:

— number of network points;
— number of districts in the delimited area;
— network data:
 · points;
 · distance between points;
 · connection between points;
— destination traffic matrix;
— points generating passengers within the district, and passenger traffic distribution.

The input data is given by the destination traffic matrix between the actual and the planned districts and the network system, as well as their relation. The network will be mapped by a graph of points and arises. Points except from changes affecting the public transport (such as crossings, junctions, partings, passenger release and intake points) have to be chosen. Thereafter point distances are stated. The destination traffic matrix will be fitted to the network graph, it yields travels between districts of the delimited area. Other data needed are network point(s) that are starting and destination points within a district. Distributions for both departure and arrival have to be known

Algorithm of the program (Fig. 1):

First, the complemented destination traffic matrix referring to network points and involving travel demands will be established. Then the shortest route among points of departure and arrival matching terms in the destination traffic matrix will be chosen. Third, passengers will be superimposed on arises in the shortest route.

Outputs:

— shortest routes between points of departure and arrival in terms of the complemented destination traffic matrix;
— superpositions on network arises in each direction;
— total passenger kilometers.

Range of the evaluable measures:

— Change of line elements, creation or elimination of points or arises. Its effect on the other elements and the passenger/km performance (such as study of the effect of traffic diversion).
— Effect of the land use change on network superposition and passenger/km performance (such as creation or elimination of points generating or attracting traffic; within a district, change of location and distribution of travel starting and end points).

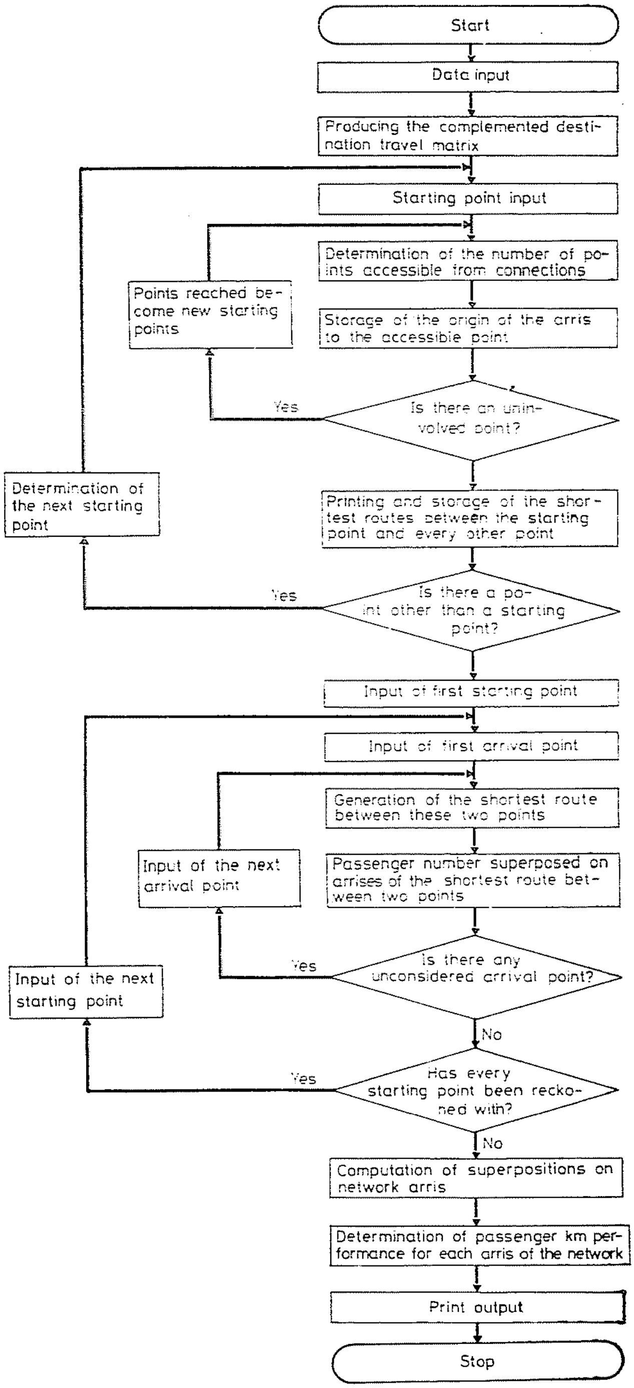

Fig. 1. **Flowchart scheme of the network superposition program**

b) *Line superposition model:*

Input:

— input data of network superposition model (public transport network, destination traffic matrix);
— number of lines;
— (average) time loss due to changing transport means;
— line characteristics:
  · mark, code;
  · headway;
  · mean travel speed;
  · allotted vehicle capacity;
  · line route (network points contacted by the line throughout the journey).

Algorithm of the program (Fig. 2):

The program determines the travel route between starting point and destination point for each term of the complemented destination traffic matrix. However, the problem is not to find the shortest route as to distance but the shortest route as to travel time. In defining the travel time between two points, the program relies on the reduced access time involving the average waiting time for the vehicle, the travel time value along a route, changing time if needed, and travel time on another vehicle. Thus, the program omits times of walking between access times.

The program defines the route involving change points and lines used along route sections.

Passenger demands between two points are fitted to the corresponding line section to yield the passenger time needed to meet the demand.

The program collects superpositions on each arise for a line, and selects the busiest section.

The needed vehicle number and vehicle/km performance are computed for each line. Of course, the number of vehicles is only determined for a computed journey time.

Characteristics for the area as a whole are continuously stored throughout the computation.

Outputs:

— line(s) utilized between starting and end points belonging to each term of the complemented destination traffic matrix, changing point(s), travel needs, passenger time demand;
— concerning lines:
  · journey length;

- needed number of vehicles;
- capacity/km performance;
- encumbrance of route sections and maximum encumbrance location;

— concerning the network:
- capacity/km performance;
- total number of vehicles.

Range of evaluable measures:

— effect of each network alternative and modification on time expenditure and on operating characteristics;
— effect of the modification of some elements (line or route) of the line system on passengers and on operational characteristics (such as to launch or to stop a line, or a route modification due to traffic diversion);
— modifications within the line:
- headway modification;
- alteration of travel speed along the route or some sections;
- alteration of the vehicle type (capacity);

— effect of all these on changings, travel time, number and performance of vehicles.

The effect of developments affecting the public transports of the Csepel district relying on the computer model will be presented as an example.

Public transports of the district relied on the suburban railways (HÉV) from Boráros tér to Csepel, and the No. 14 bus line. Until September 1st, 1984, out of them

— five lines (52, 52A, 59A, 71, 159) provided for the transports inside the district;
— nine lines passed the district:
- no. 79 took to Soroksári street on the north;
- four lines passed through Gubacsi bridge (no. 48 to Kőbánya-Kispest station, no. 51 to Zalka Máté square, no. 59 to South-Pest Hospital, and no. 148 to Gubacsi street;
- four lines passing the district to the south supplied the outskirts (nos 38, 38A, 38B, 38 rapid).

In 1984, the Budapest Transport Company has modified four bus lines of the Csepel bus network and line system. These modifications improved the areal supply, increased the network density, accelerated the travel speed in some lines, increased the number of travels without changing, improved the exploitation of vehicles in the network, evenness and trueness to timetable (Table 1).

Alterations comprised lengthening of two lines (nos 71 and 79), and the creation of a new line (no. 152) to carry part of the transport capacity along one line (no. 52), thereby increasing the public transport network system. One line (no. 52A) had been eliminated. Line alterations have been the following:

Lengthening the route of bus no. 79 to Tanácsház square has long been planned. This alteration did not involve any network increase but traveling from southern areas of Csepel to northern job places required changing once, instead of the earlier twice.

Bus line no. 71 has been lengthened by about 500 m southward to the so-called Anglers' Inn, adding to both network length and number of stations.

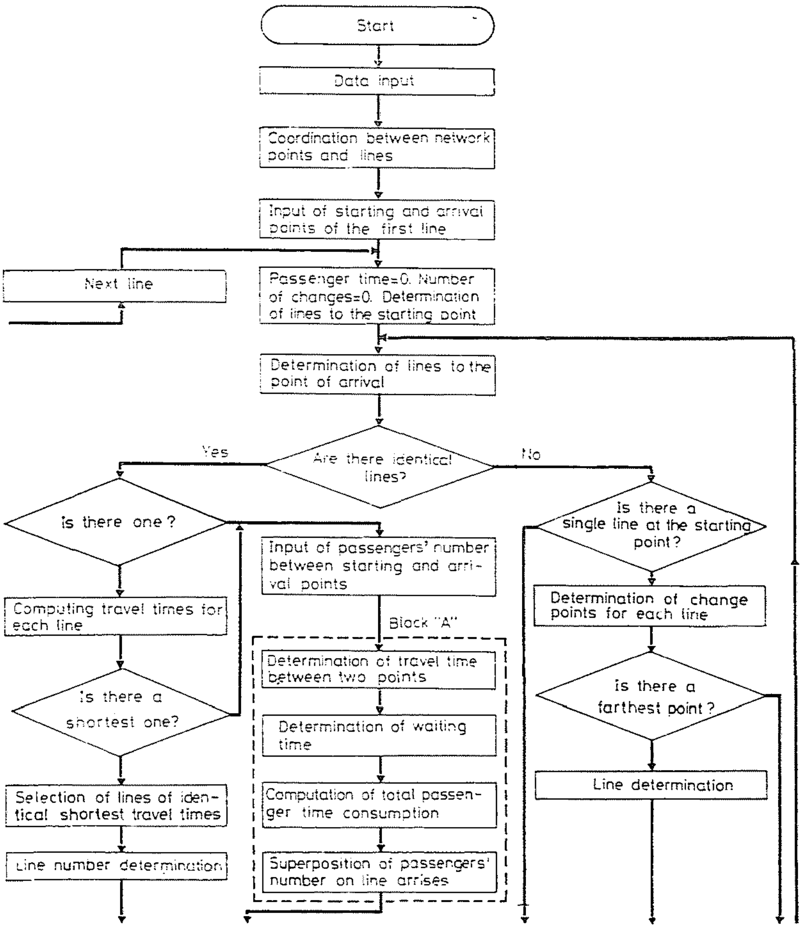

Fig. 2. Flowchart scheme of the line superposition program

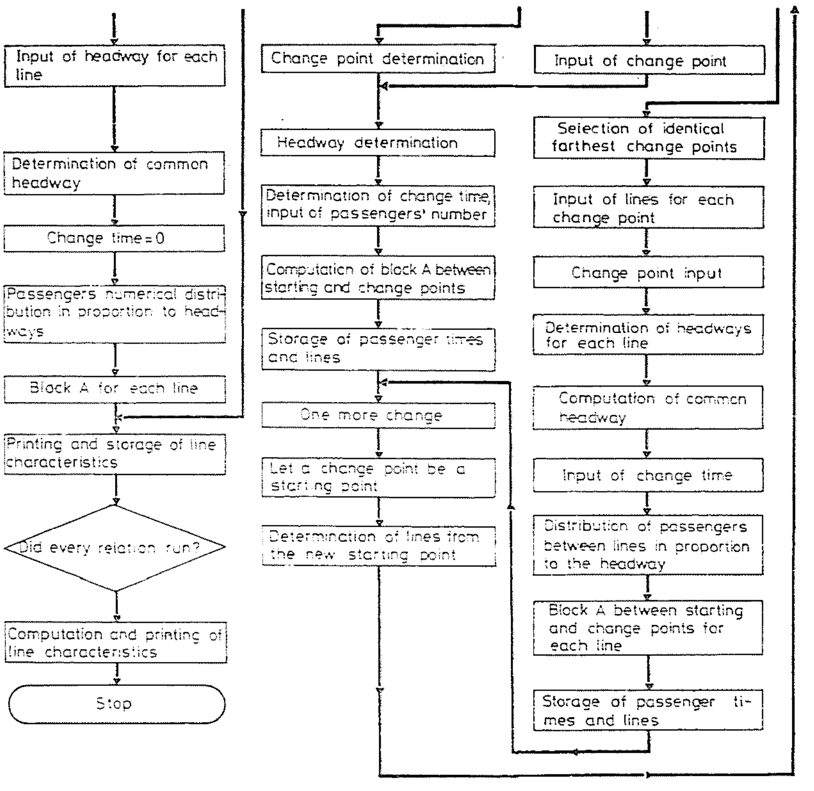

Fig. 2

Table 1

Areal supply characteristics of the public transport network of Csepel

Feature	Before modification	After modification
Network length (km)	37.7	41.7
bus	33	37
HÉV	4.7	4.7
Number of stations	140	157
bus	136	153
HÉV	4	4
Station density (in inhabited areas) (number/sq · km)	9.09	10.19
Network density (in inhabited areas) (km/sq · km)	2.44	2.71
Mean access walking (in inhabited areas) (m)	269.2	265.6

Before starting canalization works in J. Kalamár street, Szentmiklósi street obtained a pavement strong enough to support traffic diversion comprising autobuses supplying part of the area. After completion of the construction, work the capacity of the earlier bus no. 52 was divided, launching a new line no. 152 as of September 1st. The downtown terminal of the new line has been accommodated in Tanácsház square, a modification adding 3500 m and bidirectionally 16 stations to the network. At the same time, line no. 52A has been stopped.

These network developments made the public transport of Csepel areally adequate until residential areas in the south are completed, and the changes will permit to reach the nearest bus or HÉV station within 400 m from anywhere in the inhabited area.

The effect of the modifications can be evaluated by means of the computer program. Network and line modifications have been reckoned with by modifying input parameters (passenger flow matrix, network model, line system).

The passenger flow matrix relies on destination traffic counts made by the Budapest Transport Company in 1983, underlying a part matrix of nine districts and three cordon points. The matrix for the all-day transport demand was underlying the peak-hour destination traffic matrix, complemented as to permit superposition of part of the traffic generated in or directed to part of the districts to at least two points.

Distribution inside the district was made according to proportions of passengers getting on, and off vehicles as obtained by a KNORR data collector.

The starting network model was constructed according to the situation preceding the alteration on September 1st, 1984. Modifications introduced two new network arises and changed points. The original system of lines, lengthening of lines nos 79 and 71, and the added line no. 152 were denoted as alternatives A, B, B', and E, respectively.

The effect of network modifications can be evaluated in terms of characterictics (Table 2).

Table 2

Parameters of public transport network and line alternatives

Alternative	A	B	B'	E
Total network load, passenger km/h	87 465	87 465	87 519	89 808
No change	15 930	16 015	16 015	16 015
1 change	5 460	5 689	5 689	5 689
2 changes	423	111	111	111
3 changes	2	0	0	0
Total of passengers	21 815	21 815	21 815	21 815
Passenger time (h)	5 055	5 005	5 008	5 147
Passenger km performance	88 505	88 510	88 564	90 550
Reduced travel speed (km/h)	17.51	17.68	17.69	17.59
Capacity km performance	216 504	217 790	218 106	215 390
Vehicle km performance	1 470	1 487	1 491	1 467
Number of vehicles	86	86	86	86

The effect of lengthening lines nos 79 and 71 appears from comparing alternatives A, B, and B'. Network loads hardly differ.

Times spent by passengers decreased at an essentially inaltered passenger/km performance.

Numbers of no-change and single-change travels increased, to the detriment of two and three changes. The latter essentially vanished.

The number of vehicles remained the same, despite an increase of capacity/km and vehicle/km performances.

Creation of line no. 152 may be evaluated by running B—E. For the passengers, this alternative may be considered as favourable in spite of the increase of time spent and of passenger/km performance. Namely, these indices refer to times spent in the network, just as does the reduced access speed. Walking time needed to reach the network is omitted. In this alternative, just part of the walking time and distance are undertaken by the public transport network causing an increase.

Operationally, there were two possibilities. Either to operate the new line no. 152 by vehicles of line no. 52, viz. alternative E, where operational characteristics are practically equal to those of alternative B. Or, to let line no. 52 inaltered and yet to run the new line no. 152, at a significant increase of performance unmatched by the increase of travel demands. The need in vehicles of line no. 152 was rightly supplied from vehicles of line no. 52.

In conclusion, the computer model is seen to lend itself to evaluate modifications of the network and of the line system, as well as to rate any measure of organization or management affecting the travel time and speed. The method can be applied both in design and in operation.

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