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THE EXPLOITATION OF SIMULATION FOR SELECTION OF ALTERNATIVES OF TRANSPORT SERVICE FOR A ZONE BY PUBLIC TRANSPORT.

KORIŠĆENJE SIMULACIJE U IZBORU ALTERNATIVNIH OBLIKA USLUGA PREVOZA U ZONI OD STRANE JAVNOG TRANSPORTA.

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Abstract: *The article deals with the possibility of simulation exploitation by selection of alternatives for transport service of zone by public transport.*

Key words: *Simulation, Modelling, Public transport, Transfer, Travel time.*

Apstrakt: *Ovaj članak se bavi mogućnošću korišćenja simulacije u izboru alternativnih oblika usluge prevoza u zoni od strane javnog prevoza.*

Ključne reči: *simulacija, modeliranje, javni prevoz, prenos, vreme putovanja.*

1 INTRODUCTION

The computer simulation and modelling offer wide range of possibilities for exploitation in exploring of transport processes. One of the possibilities for simulation exploitation is comparing various alternatives of traffic service for certain zone by public city transport. The alternatives can differ in various number and lines routing, in vehicles capacity, in line intervals etc. There is possible to select the optimal solution for traffic service by monitoring the value of the target function.

1. UVOD

Kompjuterska simulacija i modeliranje nude širok spektar mogućnosti za korišćenje prilikom istraživanja procesa transporta. Jedna od mogućnosti za korišćenje simulacije jeste poređenje različitih alternativnih oblika prevoza za određenu zonu od strane javnog gradskog prevoza. Alternative se mogu razlikovati u različitom broju i rutiranju linija, kapacitetu vozila, vremenskom intervalu između linija itd. Može se odabrati najbolje rešenje za usluge prevoza putem praćenja vrednosti ciljane funkcije.

2 THE SIMULATION OF A TRAFFIC SERVICE FOR A ZONE BY PUBLIC TRANSPORT

2.1 The Simulation Tool

We have used the commercial system „*Extend*" produced by *Imagine That, Inc.* for creation of

2 SIMULACIJA USLUGE PREVOZA ZA ZONU OD STRANE JAVNOG PREVOZNOG PREDUZEĆA

2.1 Alati za simulaciju

Koristili smo komercijalni sistem „*Extend*" koji je proizvela kompanija *Imagine That, Inc.* za

the simulation model. The system also offers the possibility to develop own libraries and blocks except of running the wide range of simulations. There is possible to generate dynamic models of real processes in various areas by using the system. The models creation from developed blocks allows to study difficult processes as well as to see how are they connected each other and finally by the changing of their parameters to find optimal solution. „*Extend*" allows simple and fast construction of difficult models for various systems, processes and facilities. There is also possible to create the block schemes of processes and facilities, where every block describes a part of the process or the facility in the system.

The generation of models is allowed by the existence of libraries with many prepared blocks which can be used by a model creator. Individual blocks can be easily connected one another by connecting of their inputs and outputs. Such connected blocks can be then grouped into hierarchical blocks due to simplicity and lucidity. The advantage of the tool is the requirement for minimal experience with programming for a model creator.

2.2 The simulation model

2.2.1 The simulation model conception

The basic conception of the simulation model is based on simulation of passengers flow from the place of their getting on to the place where they get off. The transport between the places is realised by the flow of means of transportation (vehicles).

stvaranje simulacionog modela. Ovaj sistem takođe nudi mogućnost da se izrade sopstvene datoteke i blokovi osim pokretanja širokog spektra simulacija. Korišćenjem sistema moguće je generisati dinamične modele stvarnih procesa u raznim oblastima. Stvaranje modela iz razrađenih blokova omogućava proučavanje težih procesa kao i to da se stekne uvid u to kako su povezani jedan sa drugim i najzad, menjanje njihovih parametara kako bismo našli optimalno rešenje. „*Extend*" omogućava jednostavnu i brzu izgradnju teških modela za različite sisteme, procese i postrojenja (uređaje). Takođe je moguće napraviti blok dijagrame procesa i uređaja, gde svaki blok opisuje deo procesa ili uređaja u sistemu.

Ova generacija modela je omogućila postojanje datoteka sa mnogim pripremljenim blokovima koje može koristiti projektant modela. Pojedinačni blokovi se mogu lako povezati jedan za drugi tako što se povežu njihove ulazne i izlazne vrednosti. Tako povezani blokovi se mogu grupisati u hijerarhijske blokove zbog jednostavnosti i jasnoće. Prednost ovog alata je uslov za posedovanjem minimalnog iskustva u programiranju potrebnog za izradu modela.

2.2 Simulacioni model

2.2.1 Ideja simulacionog modela

Osnovna ideja simulacionog modela je zasnovana na simulaciji kretanja putnika sa mesta u kome ulaze u prevozno sredstvo do mesta na kome izlaze iz sredstva. Transport između ta dva mesta se vrši putem kretanja prevoznih sredstava (vozila).

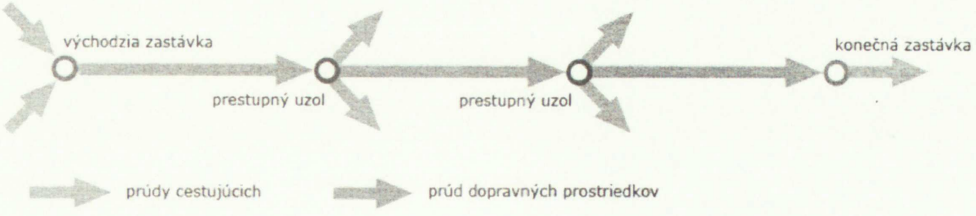

Figure 1 The basic conception of the simulation model
slika1 Osnovna ideja simulacionog modela

Passengers can change the vehicle (transmission into the other line) in through stops (through nodes). The possibility of transmission is in the model limited to 1 transmission.

Putnici mogu da promene vozilo (prebacivanje na drugu liniju) na prolaznim stanicama (prolaznim čvorištima). Mogućnost prenosa nalazi se u modelu koji je ograničen na 1 prenos.

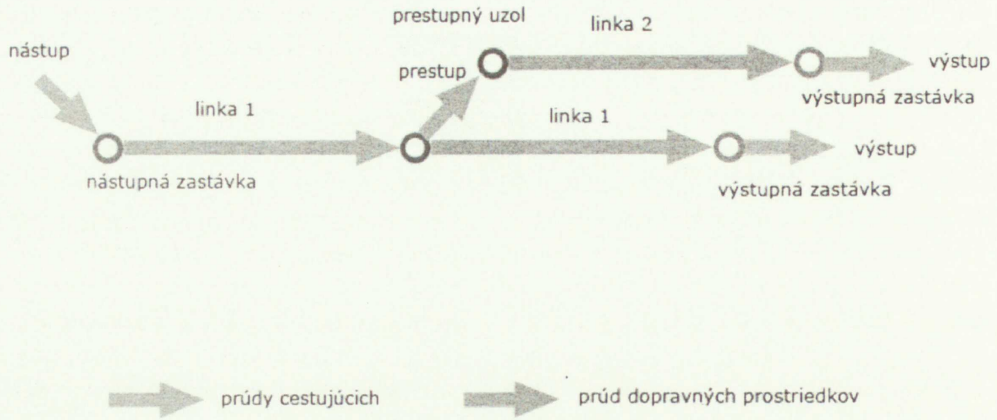

Figure 2 A transmission between lines
slika 2 Prenos između linija

The simulation model consists of individual hierarchical blocks. A hierarchical block represents a group of basic blocks into the greater whole that are available from *„Extend"* system libraries.

Simulacioni model se sastoji od pojedinačnih hijerarhijskih blokova. Hijerarhijski blok predstavlja grupisanje osnovnih blokova u veću celinu koja se može videti u sistemskim bibliotekama *„Extend"*.

Exploitation of hierarchical blocks allows to group blocks into logical groups representing the model structure. In the simulation model the five basic hierarchical blocks are used that can be copied and connected and so simply create model variations. The basic hierarchical blocks are:

Korišćenje hijerarhijskih blokova omogućava da se blokovi grupišu u logičke skupine koje predstavljaju strukturu modela. U simulacionom modelu koriste se pet osnovnih hijerarhijskih blokova koji se mogu kopirati i povezati i tako se mogu jednostavno napraviti varijacije modela. Osnovni hijerarhijski blokovi su sledeći:

- vehicles (vehicle generator),
- initial stop,
- through stop (through node),
- final stop,
- segment between stops.

- vozila (generator vozila),
- početno stajalište,
- prolazno stajalište (prolazno čvorište),
- krajnje stajalište,
- segment između stajališta.

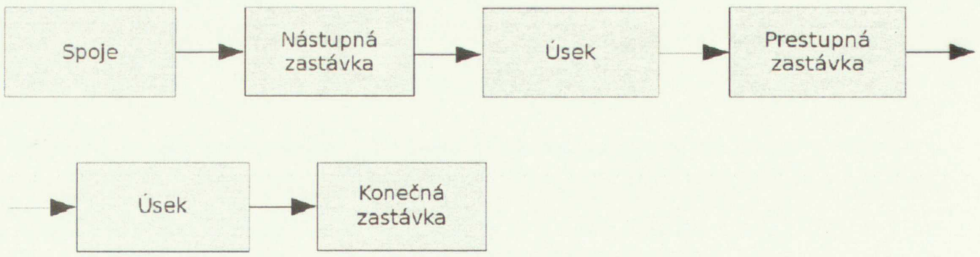

Figure 3 Basic hierarchical blocks of the simulation model
slika 3 Osnovni hijerarhijski blokovi simulacionog modela

The basic hierarchical blocks represent static model elements. The dynamic elements are:

Osnovni hijerarhijski blokovi predstavljaju statičke elemente modela. Dinamički elementi su:

- lines,
- passengers,
- the group of passengers.

- linije,
- putnici,
- grupa putnika.

Passengers come to the initial stop individually where they wait for vehicle of the chosen line. Then after vehicle arrival the passengers are grouped into groups according to target stop (journey direction). Every passenger group is determined by journey direction and by the number of passengers.

Putnici dolaze pojedinačno na početnu stanicu gde čekaju vozilo odabrane linije. Zatim, nakon dolaska vozila, putnici se grupišu u skupine prema ciljanoj stanici (pravac putovanja). Svaka grupa putnika je određena pravcem putovanja i brojem putnika.

2.2.2 Model variables and parameters

2.2.2 Promenljive i parametri modela

The function of the model is transformation of input variables according to defined relations and parameters into the output variables. Variables change their value during simulation while model parameters stay constant.

Funkcija ovog modela je pretvaranje promenljivih ulaznih vrednosti prema definisanim odnosima i parametrima u promenljive izlaznih vrednosti. Promenljive menjaju svoju vrednost tokom simulacije dok parametri modela ostaju konstantni.

The input variables are:

- transport interval in common line (lines),
- number of travellers getting on initial stops.

Ulazne promenljive su:

- interval između dolaska prevoza u običnoj liniji (linijama),
- broj putnika koji ulaze na početnim stanicama.

Model parameters are represented by:

- capacity of means of transport ,
- segment travelling times ,
- transport interval in exchange lines,
- rate of transmitted passengers,
- walk time in through stops,
- spare time.

Parametre modela predstavlja:

- kapacitet prevoznog sredstva,
- vreme putovanja kroz segment,
- interval prevoza kod presedačkih linija,
- stopa preveženih putnika,
- vreme prolaza kroz prolazne stanice,
- slobodno vreme.

Output variables:

- value for total transportation time,
- wait times in initial stops,
- wait times in through stops,
- number of through passengers ,
- utilization of individual vehicles.

Izlazne promenljive:

- vrednost ukupnog vremena u prevozu,
- vreme čekanja na početnim stanicama,
- vreme čekanja na prolaznim stanicama,
- broj putnika u prolazu,
- korišćenje privatnih vozila.

As the data source can be used direction survey of public transport with O/D matrix (matrix of sources and targets) that express particular transport relations between zones (in case of segmentation into zones) or stops in case of exploitation the existing public transport network.

Pošto se izvor podataka može koristiti za ispitivanje pravca javnog prevoza sa O/D matricom (matrica izvora i ciljeva) koje izražava posebne odnose u prevozu između zona (u slučaju podele na zone) ili stanica u slučaju korišćenja postojeće mreže javnog prevoza.

For evaluation of individual model variants the value of total transport time T_{celk} is important. The value express the sum of times that are necessary for tranport of all passengers:

Za procenu pojedinačnih varijanti modela, važna je vrednost ukupnog vremena u prevozu T_{celk}. Ova vrednost izražava iznos vremena koje je potrebno za prevoz svih putnika:

$$T_{celk} = \sum_{i=1}^{m} T_i \quad (1)$$

$$T_i = T_{či} + T_{dpi} + T_{prei} + T_{chi} \quad (2)$$

$$T_i = (t_č + t_{dp} + t_{pre} + t_{ch}).C_i \quad (3)$$

where:
T_{celk} – total transport time, [min.]
T_i – transport time for i^{th} passenger group, [min.]
m – number of passenger groups, [-]
$T_{či}$ – wait time for i^{th} passenger group, [min.]
T_{dpi} – time of stay in vehicle for i^{th} passenger group , [min.]
T_{prei} – through time for i^{th} passenger group, [min.]
T_{chi} – walk time for i^{th} passenger group, [min.]
$t_č$ – wait time for vehicle, [min.]
t_{dp} – time of stay in vehicle, transport time, [min.]
t_{pre} – through time, [min.]
t_{ch} – walk time to and from stop from source and to transfer target, [min.]
C_i –passengers number for i^{th} group. [person]

By analogy the created model can be also used for vehicles coordination in through nodes. In the case the value of through time will be monitored with the aim to minimize its value.

Figure 4 describes the block scheme for hierarchical block *"Through stop"*. Figure 5 shows the block scheme transcription in *„Extend" system.*

$$T_{celk} = \sum_{i=1}^{m} T_i \quad (1)$$

$$T_i = T_{či} + T_{dpi} + T_{prei} + T_{chi} \quad (2)$$

$$T_i = (t_č + t_{dp} + t_{pre} + t_{ch}).C_i \quad (3)$$

gde je:
T_{celk} – ukupno vreme u prevozu, [min.]
T_i – vreme u prevozu za i^{tu} grupu putnika, [min.]
m – broj grupa putnika, [-]
$T_{či}$ – vreme čekanja za i^{tu} grupu putnika, [min.]
T_{dpi} – vreme boravka u vozilu za i^{tu} grupu putnika, [min.]
T_{prei} – prolazno vreme za i^{tu} grupu putnika, [min.]
T_{chi} – vreme hodanja za i^{tu} grupu putnika, [min.]
$t_č$ – vreme čekanja za vozilo, [min.]
t_{dp} – vreme boravka u vozilu, vreme transporta, [min.]
t_{pre} – prolazno vreme, [min.]
t_{ch} – vreme u hodanju ka i sa mesta polaska i ka destinaciji, [min.]
C_i –broj putnika za i^{tu} grupu putnika. [osoba]

Po analogiji, stvoreni model se takođe može koristiti za koordinaciju vozila na prolaznim čvorištima. U tom slučaju, pratiće se vrednost prolaznog vremena u cilju minimizacije njegove vrednosti.

Slika 4 opisuje blok dijagram za hijerarhijski blok *„Prolazna stanica"*. Slika 5 pokazuje transkripciju blok dijagrama u *„Extend" sistemu.*

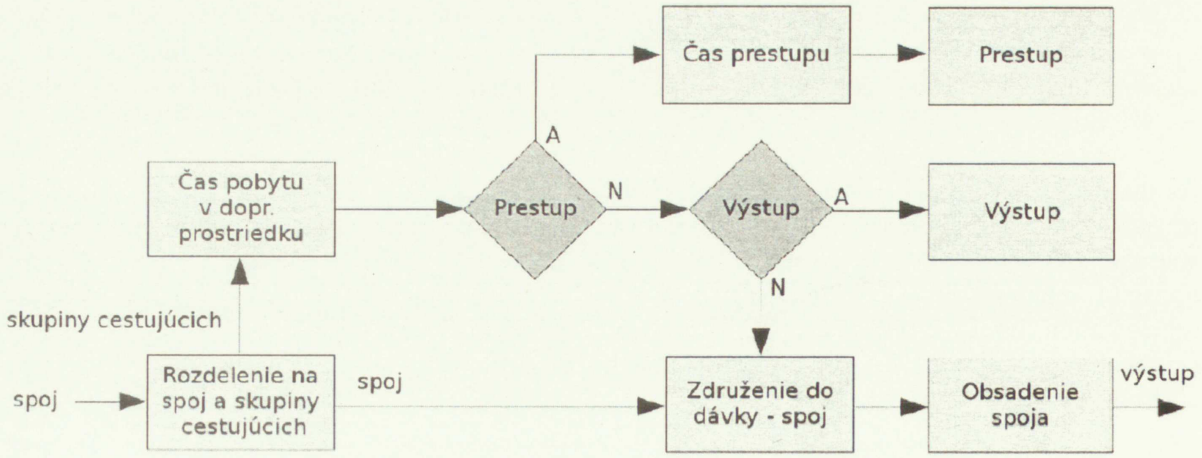

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Figure 4 The block scheme of the hierarchical block „Through stop"
slika 4 Blok dijagram hijerarhijskog bloka „Prolazna stanica"

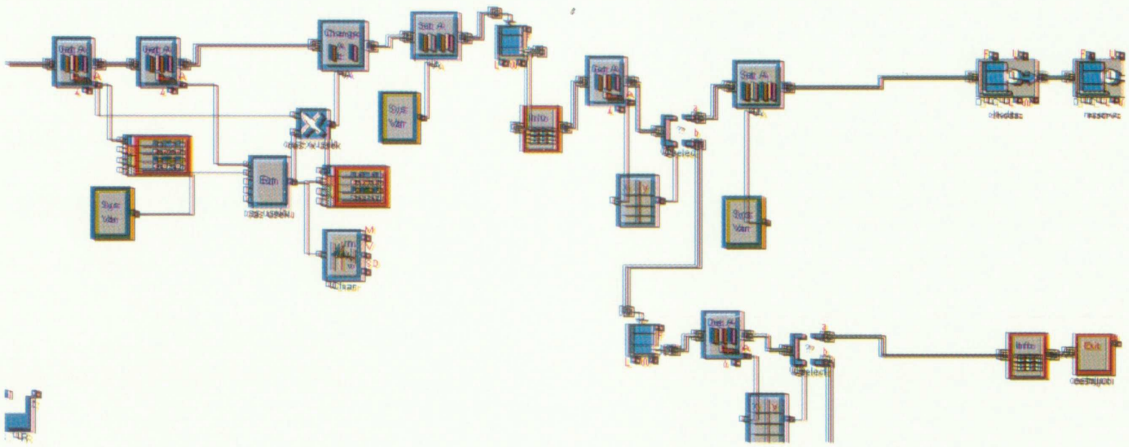

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Figure 5 The hierarchical block „Through stop" in Extend system
slika 5 Hijerarhijski blok „Prolazna stanica" u Extend sistemu

3 CONCLUSION

Exploitation of simulation and modelling in transport process observation in city public transport allows comparison and selection of alternatives for traffic service. The computer simulation offers higher flexibility and more simple generation of complex multilevel models in contrast to mathematical models. The advantage is also possibility of animation for simulation process as well as simulation results.

3 ZAKLJUČAK

Korišćenje simulacije i modeliranja u posmatranju procesa transporta u javnom gradskom prevozu omogućava poređenje i izbor alternativnih oblika saobraćajnih usluga. Kompjuterska simulacija nudi veću fleksibilnost i jednostavnije generisanje složenih višestepenih modela naspram matematičkih modela. Prednost takođe predstavlja mogućnost da se animiraju procesi simulacije kao i rezultati simulacije.

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