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TIME BENCHMARKING IN URBAN TRANSPORT QUALITY

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Abstract: *Among various quality indices, the in-vehicle, the waiting time and the interchange time are three of the most important components of the journey time, playing a significant role in the estimation of the generalized cost of travel. The frequency of the public transport service depends not exclusively on fleet size and scheduling conditions, but also on traffic safety conditions. Using computer simulation one estimates the passengers waiting time, reneging proportion and level of comfort for urban light rail with dedicated infrastructure.*
Key words: *urban transport quality, generalized cost of travel, passengers waiting time.*

INTRODUCTION

Each individual, faced with transportation needs, is looking for a flexible, independent and as fast as possible service. The reconciliation of individual aspirations and social will, that are mainly contradictory, is provided through qualitative public transport that induces shifting from individual modes to public transport. The transport quality has a double mean – passengers satisfaction and conformity for the supplier [1,2]. Expected quality reflects user's legitimate and normal expectations. This is not an unrealistic concept, beyond the technological and economic reality, but one to which the supply should permanently be related. The desired quality reflects the wishes of the suppliers or local authorities. The achieved quality results during the service process. The perceived quality is the customer perception of the service, based on its experiences. The bias between the expected and the achieved quality urges the supplier to understand better the user's expectations, to determine the most relevant aspects for them. The gap between the desired and the achieved quality reflects the effectiveness of the suppliers. The difference between the achieved and the perceived quality reflects the efforts of the suppliers versus user's satisfaction. The gap between the expected and the perceived quality shows the degree of customer's satisfaction.

The public transport quality is measured by a system of indices related to accessibility, duration of trip, comfort, reliability, safety and security, capacity, information and monitoring [2,3].

Shaping a detailed expression of desired quality makes possible to define managerial tools for improving quality of public transport and to assess the system's performance.

GENERALISED COST OF TRAVEL

The cost elements of a trip may be considered in terms of distance, time or money units. Usually, the generalized cost of travel between two points (Cij) by public mode is referred as a linear function of the attributes of the journey weighted by coefficients reflecting their relative importance as perceived by the user (Eq. 1).

$$C_{ij} = \alpha_1 t_{ij}^v + \alpha_2 t_{ij}^f + \alpha_3 t_{ij}^w + \alpha_4 t_{nij} + \alpha_5 F_{ij} + \delta \qquad (1)$$

where:

t_{ij}^v is the in-vehicle travel time between origin and destination;

t_{ij}^f - the walking time to and from stations;

t_{ij}^w - the waiting time at stations;

t_{nij} - the interchange time;

F_{ij} - the fair charged to travel between origin and destination;

δ - modal penalty, representing all other attributes not included explicitly in the generalized measure (e.g.: safety, comfort, convenience);

$\alpha_{1...5}$ - weights with appropriate dimensions for conversion of all attributes to common units.

The generalized cost of travel represents an interesting compromise between subjective and objective disutility of movements [4]. There are some theoretical and practical advantages in measuring generalized cost in time units. If generalized cost is measured in unit currency, the income levels increasing with time will increase the value of time and therefore increase generalized cost and apparently makes the same destination more expensive. If on the other hand, generalized cost is measured in time units, increased income levels would appear to reduce the cost of reaching the same destination, and this is intuitively more acceptable.

The in-vehicle travel time, the waiting time in stations and the interchange time are time components of the generalized cost that reflect the achieved quality of the service. The in-vehicle travel time depends on vehicle average speed, which is influenced by technical (the vehicle and infrastructure possibilities), management or legal aspects (limited speed). The waiting time is the expression of the frequency and regularity of the service, but also vehicle capacity and comfort requirements could influence it. The interchange time depends on the topology and design of he stations.

Passengers perceive the elapse of time differently for each stage of the trip. One minute of walk time, wait time and transit time is perceived by customers as being two or three time more onerous as one minute of in-vehicle time [3,4].

ANALTYCAL MODEL FOR EVALUATING WAITING TIME

Passengers flow arriving at stations have a stochastic component beside a predictable one due to connections with vehicles schedule and temporal non-uniformities [5]. The non-uniformities premises are of economic (seasonality of activities, holidays), organizing (the schedule of economic agents activities) or technical nature (dysfunction in system activity).

Some psychological aspects of users' behavior generate aspects such as:

- ♦rejecting – the refuse to use the public transport because of the crowdedness;
- ♦reneging – the abandon of the system because of the long waiting time;
- ♦jockeying – changing the transport mode or waiting area with the scope of reducing the waiting time.

The customers' waiting time can be evaluated using the queuing theory. For the public transport, the customers' service is a bulk service. The passengers waiting in a station are boarding in a vehicle, limited by the number of available places. If waiting places and vehicles capacity are sufficient, the rejecting phenomena are excluded.

The cumulative arrival A(t) and departure D(t) diagram for passengers deterministic flows are depicted in figure 1.

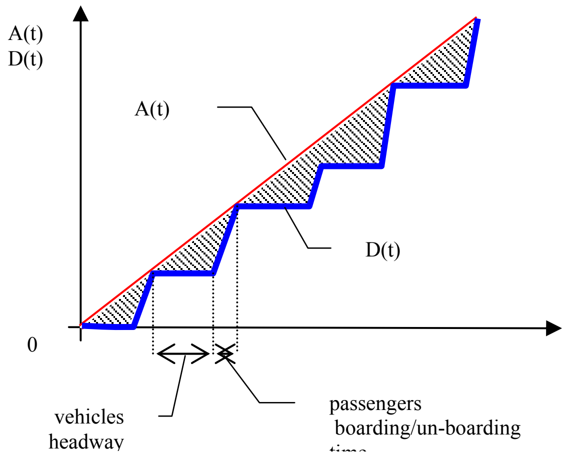

Fig. 1 Cumulative arrivals and departures

The area between the two curves represents the total waiting time. Due to capacities constraints, some of the customers cannot board in the first vehicle and they have to wait for another one.

For stationary arrivals of customers, Little [6] stated the relation (Eq. 2) between the expected number of waiting customers ($\overline{N}_w$) and the average waiting time ($\overline{T}_w$).

$$\overline{N}_w = \lambda \overline{T}_w, \qquad (2)$$

where λ is the arrival rate.
The total waiting time during a period T is

$$T_w = \int_0^T [A(t) - D(t)]dt . \qquad (3)$$

For a deterministic flow, the number of arrived customers is $N = \lambda T$. Thus, the average waiting time is

$$\overline{T}_w = \frac{\int_0^T [A(t) - D(t)]dt}{\lambda T}. \quad (4)$$

According to Little's formula, the average number of waiting passengers is

$$\overline{N}_w = \frac{\int_0^T [A(t) - D(t)]dt}{T}. \quad (5)$$

The number of waiting passengers is an important factor in dimensioning the waiting area, especially for "island" zones, surrounded by infrastructures.

EVALUATING WAITING TIME THROUGH COMPUTER SIMULATION

For stochastic flows, the deterministic models have limited feasibility. Digital simulation is more adequate for estimating the measures of performances used in the design of the public transport system [2,7]. For evaluating the waiting time, one set-up a simulation program (Fig. 2).

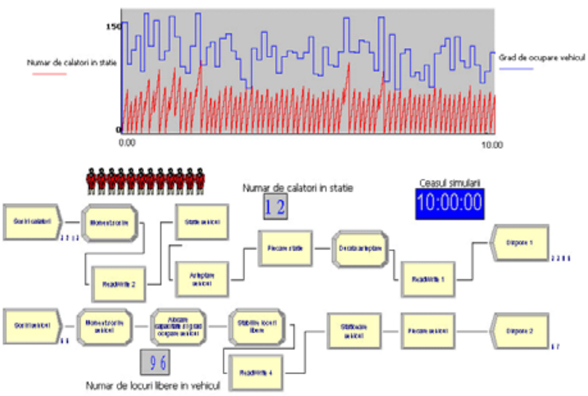

Fig. 2 Computer simulation diagram

The simulation experiments are done for an urban light rail in the following hypothesis:

♦the arrival process has a Poisson distribution of parameter $\lambda = 3...6$ passengers/minute;

♦the vehicles' headway has a normal distribution of average $\bar{t}_u = 6...11$ minutes and standard deviation $\sigma = 0.6...1.1$ minutes;

♦the occupancy degree of the vehicle has a triangular distribution with minimum limit 0.3, mode 0.6 and maximum limit 0.9;

♦the vehicle stationing time is proportional with the number of boarding/un-boarding passengers on a vehicle door; for each passenger a constant time of 2 seconds is assumed;

♦the vehicle capacity - 260 places;

♦simulation time - 10 hours;

♦the warm-up simulation time - 1 hour, considered sufficient enough to smooth the effect of the initial state and reaching the steady state [5].

Figure 3 depict the variation of the average waiting time with the headway between vehicles and arrival rate.

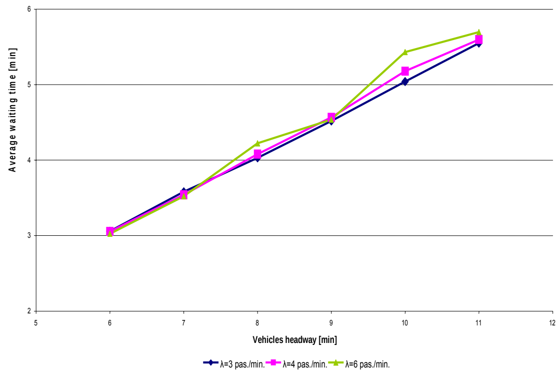

Fig. 3 Passengers average waiting time

The statistical analysis of simulation data confirms an empirical dependency of the average waiting time on vehicles average headway and their standard deviation [8].

$$\overline{T}_w = \frac{\bar{t}_u^{\,2} + \sigma^2}{2\bar{t}_u} \quad (6)$$

The determination coefficient R^2, obtained by comparing the simulation results with the analytical values, is considerately close to 1. Thus, one concludes that the customers' average waiting time does not depend of arrival process. On the other hand, the number of waiting customers is dependent of customers' arrival distribution and vehicles headway (Fig. 4).

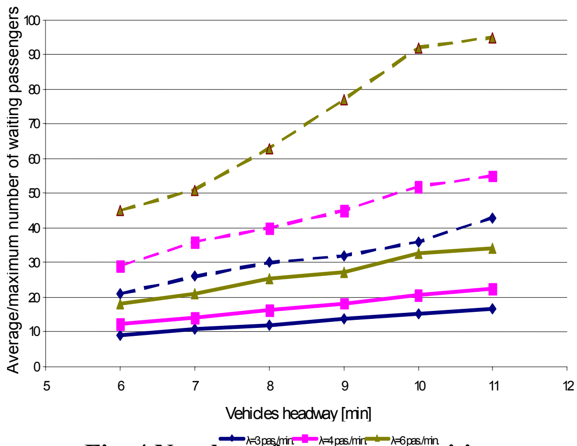

Fig. 4 Number of passengers waiting

The vehicle headway, the arrival rate and the occupancy rate are determinant for the rejection probability of customers that are not boarding in the first vehicle (Fig. 5).

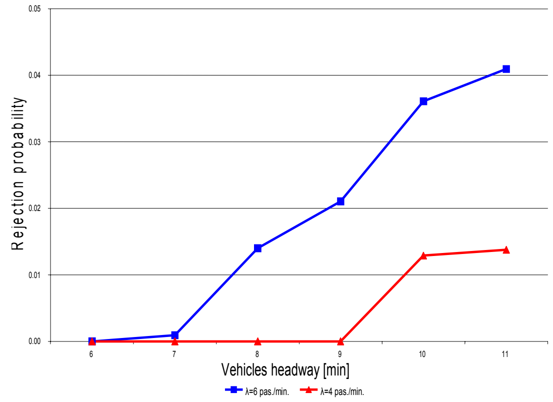

Fig. 5 Rejection probability

The rejection probability, considered an important quality index, has to be managed by the transport operator for maintaining the attractiveness of the service.

CONCLUSIONS

Increasing the deregulation process on public transport means that each operator should enhance the level of desired and achieved quality for be more competitive on the market. The transport operators have to face the customers' expectations, mainly during peak-hours, for obtaining their loyalty and turning them into permanent customers. Among quality indices, the travel time has a certain importance. The waiting time in stations, part of the total travel time, can be reduced by providing smaller headway, smoothing its variance and increasing vehicles capacity. Any action to improve public transport quality involves certain costs that must be assumed as an investment, justified by the future benefits for customers, operators and community as a whole.

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СЪПОСТАВИТЕЛНО ИЗСЛЕДВАНЕ НА ВРЕМЕТО В ГРАДСКИЯ ТРАНСПОРТ

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РУМЪНИЯ

Резюме: *Сред различните качествени показатели времето в превозното средство, времето за чакане и смяна са трите най-важни компоненти на времето за пътуване, които играят важна роля при преценката на обобщената стойност на пътуването. Честотата на обслужването с градски транспорт не зависи изключително от големината на парка от превозни средства и условията на разписанието, но също така и от условията за безопасност на движението. Чрез използването на компютърно симулиране се преценява времето за чакане съотношението на изоставане и равнището на комфорт в градската железници с отделна инфраструктура.*

Ключови думи: *качество на градския транспорт, обобщена стойност на пътуване, време за чакане от пътниците.*