# TRANSPORT SYSTEMS

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## INFORMATION TECHNOLOGY IN THE ORGANIZATION OF LONG-DISTANCE BUS PASSENGER TRANSPORTATION

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***Abstract.*** *The article analyzes the problems of informational support of the Organization of work, of the rolling stock transport enterprises Chernihiv. One of the important tasks of modern transportation enterprise is the development of theoretical and methodological approaches to increase the effectiveness of passenger transport in terms of variable demand on transport services. Currently, passenger-transport system in Chernihiv region has a number of problems caused by the lack of information at all levels of transport process. The authors found the optimum spacing of vehicles for intercity bus transportationthat simultaneously takes into account economic interests of carriers and passengers.*

**Keywords:** information technology; motor transport enterprise; passenger carriage; rolling stock; interval; optimization; passengers; mathematical model.

## I. INTRODUCTION. STATEMENT OF THE PROBLEM

In the study of long distance passenger transport in Chernihiv region was discovered the problem of lack of communication between the drivers of vehicles and call counts of bus stations. The main problem of interurban passenger transportation is efficient use of rolling stock and improves the quality of passenger service. Information technology in the Organization of work of transport enterprises (TE) were considered in the works [1]–[5], [8], [9]. At this time the current planning, the choice of the type of rolling stock, depending on the variable demand for intercity bus passenger transportation in Chernihiv region is "intuitive", relying on previous experience and statistical data of the previous reporting periods. This case does not use information technology that would optimize the current planning, having active database technology of processing information about daily fluctuations, weekly and seasonal changes in demand for passenger traffic on long-distance routes in the region.

## II. RESEARCH OF MOBILITY OF THE POPULATION

Statistical study of passenger traffic for the types of communications in Ukraine and Chernihiv region showed that on long-distance routes increases the mobility of the population, respectively, leads to the increase in the number of rolling stock of road transport in the regions [7]. Passenger-transport the interaction has a statistical epicycles which can formalise using harmonic analysis, which is based on the position that any dynamic range can be represented as the sum of harmonic constituents. As a rule, find only those harmonics, which define the basic laws of dynamic range for harmonic analysis is not an important cause of seasonal fluctuations, it is important to the series contained a circular component. Harmonic analysis involves the decomposition of the function, set the interval $[0, T]$, Fourier series or Fourier coefficients in the calculation. In particular, for the function $y(t) = \cos(t)$, $(0 < t < \pi)$ harmonic analysis gives three harmonics $F_1(t)$, $F_2(t)$, $F_3(t)$. Harmonic synthesis gives the fluctuations in complex form by summing their harmonic components (Fig. 1).

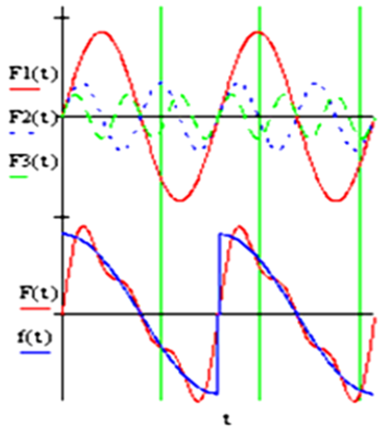


Fig. 1. Harmonic analysis and synthesis function $y(t) = \cos(t)$

Coefficients of harmonics are determined by least squares method and minimize the amount of $\sum_{k=0}^{n-1}(\hat{y}_k - y_k)^2$ squares of deviations calculated values $\hat{y}_k = \hat{y}(t_k)$ from the values $y_k$ obtained as a result of the experiment. Fluctuating flow in time

$F(t) = F_1(t) + F_2(t) + F_3(t)$, where $F_1(t), F_2(t), F_3(t)$ – daily, weekly and seasonal epicycles in traffic, between which there is such a dependency: $F_3 = 4{,}28\,F_2$, $F_2 = 7F_1$ [6].

Demand for passenger traffic on each route of Chernihiv has its amplitude-frequency characteristics (Fig. 2), which depend on a variety of socio-economic indicators of the territories of the region. The random component displays the stochastic nature of passenger transport process and the impact on it. The various factors are socio-economic, political, and organizational. When identify seasonal process is carried out by filtering the seasonal component.

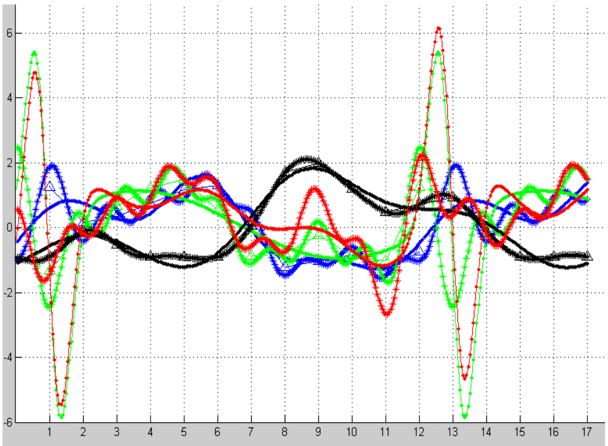

Fig. 2. Daily, weekly and seasonal changes in passenger traffic on the route "Chernihiv-Borzna"

Control system of long distance bus transport of passengers shall comply with the requirements of the veracity of the information about the processes of passenger service in real time. Dataware and forecasting of passenger-vehicle interactions between the territories of the region are necessary for effective use of the rolling stock and improvement of the quality of transport services.

## III. Information technology in the management of passengers transportation

Information model is the central database of the managing modules that provide data about passenger traffic when the functioning of the system creates a single information field that allows you to obtain the necessary data for management decision-making relative to objects management. The transfer and exchange of information between participants in the logistics information system (bus stations, bus ticket and the operators of transport services) is using the Internet. Manager module is a software complex, being built on the basis of mathematical models. Disparate information should be incorporated in the integrated logistics system, transparent for all participants in the chain. Information model should include the following elements: data on transport mobility of the population, characteristics of the carriage of passengers, the use of buses on routes the results of mathematical modeling and predictions of passenger service network development at regional level. Accurate, complete and timely information allows you to flexibly react to changes in demand for passenger traffic. Analytical data analysis about the pre-sale tickets allows you with some level of accuracy to determine the required date, time and number of additional buses for routes of transportation, popular in the population. From 2011 the bus stations of Chernihiv was introduced to the control system – automated system registrars settlement operations to increase productivity of cashiers and managers and reduce the costs of working time passenger service without lowering the quality of services. The existing database of passenger traffic is static and not used the TE for making management decisions regarding the structure and spacing of movement of vehicles (MV) flights. System of automobile passenger traffic in the region should include hardware and software for mobile objects (bus) and bus stations that could provide with minimal expenditure of coherent interaction between carriers and passengers.

## IV. Model of optimal interval movement of vehicles on the route

Competitive TE depends on the level of its profitability and quality of service for passengers. For passenger service quality improves with decreasing interval movement of vehicles on the route. Relative interval movement of the vehicle in the interests of the carrier and passengers are opposite. The carrier increases their profits by increasing the interval, and the interests of the passengers fully catered at his decline. Optimization of TE is, on the one hand, at maximum satisfaction of consumers' needs transport services, i.e. the reduction of the waiting time in the queue and the comfort of movement, and on the other, in reducing the cost of transportation on the route. When starting an optimization problem regarding modes of transport must take into account the existence of the contradiction between the interests of the operator and passengers.

We denote $P_i$ as the average passengers per $i$ th hour TE (Fig. 3), $\varepsilon$ is the coefficient of filling the vehicle by MV passengers ($0 < \varepsilon \le 1$), $K$ is the total number of MV TE, $K_i$ number of MV vehicles on this route per $i$ th hour TE, $\tau_0$ is the duration of MV traffic vehicles on route, $\tau_i$ is the optimal interval MV between flights, $N$ is the number of places in the MV, $S$ is the cost of transportation of passengers per hour, $H$ is cost per passenger-hour.

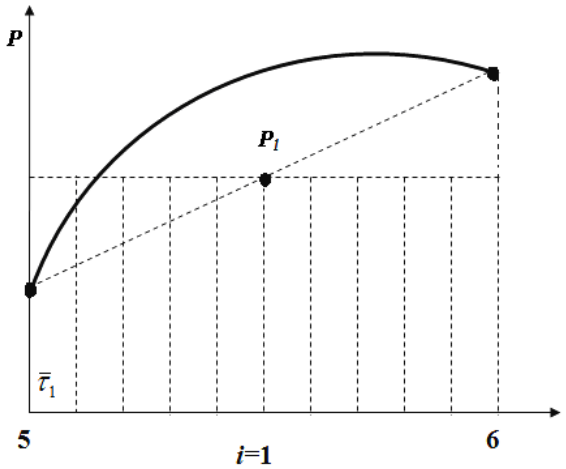


Fig. 3. Changing flow $P$ for 1 hour and spacing of movement $\bar{\tau}_1$ MV

Total costs $C$ in 1 hour consists of the costs of the carrier $C_{car}$ and the cost of the passenger $C_{pas}$. Passenger traffic on the route is 1 hour determined by the dependency:

$$P_i = \varepsilon_1 N \frac{1}{\tau_1}, \text{ where } 0 \le \varepsilon \le 1. \quad (1)$$

If $\bar{\tau}_1 < \tau_1$, then $\bar{K}_1 = \frac{1}{\bar{\tau}_1}$, $\varepsilon_1 = \frac{P_1}{\bar{K}_1 N}$, while $0 \le \frac{P_1\tau}{N} \le 1$, $\tau_1 \le \frac{N}{P_1}$, $\varepsilon_1 = \frac{P_1\tau_1}{N}$, when $K_1 N = \frac{N}{\tau_1}$, $P_1 \cdot 1 = K_1 N = \bar{K}_1 N \varepsilon$, $\varepsilon = \frac{K}{K_1}$, $P_1 = \varepsilon_1 \bar{K}_1 N$.

From these considerations we obtain the system:

$$\begin{cases} P_1\tau_1 = \varepsilon_1 N, \\ P_2\tau_2 = \varepsilon_2 N, \\ \dots\dots\dots\dots\dots, \\ P_i\tau_i = \varepsilon_i N, \\ \dots\dots\dots\dots\dots, \\ P_{17}\tau_{17} = \varepsilon_{17} N. \end{cases}$$

With equality (1) implies that $\varepsilon_i = \frac{P_i}{K_i N}$, then, according to daily intervals of MV (from 5 to 22 hrs.) The number of buses to meet the demand for passenger traffic will be determined by the equation:

$$\begin{cases} (5-6), P_1 = \varepsilon_1 K_1 N, \\ (6-7), P_2 = \varepsilon_2 K_2 N, \\ \dots\dots\dots\dots\dots\dots\dots, \\ (\dots - \dots), P_i = \varepsilon_i K_i N, \\ \dots\dots\dots\dots\dots\dots\dots, \\ (21-22), P_{17} = \varepsilon_{17} K_{17} N, \end{cases}$$

$$\begin{cases} K_1 = \frac{P_1}{\varepsilon_1 N}, \\ K_2 = \frac{P_2}{\varepsilon_2 N}, \\ \dots\dots\dots\dots, \\ K_i = \frac{P_i}{\varepsilon_i N}, \\ \dots\dots\dots\dots, \\ K_{17} = \frac{P_{17}}{\varepsilon_{17} N}. \end{cases}$$

Cost carrier $C_{car}$ calculated as follows:

$$C_{car} = \frac{K_1 NS}{\varepsilon_1} + \frac{K_2 NS}{\varepsilon_2} + \dots + \frac{K_{17} NS}{\varepsilon_{17}} = NS \sum_{i=1}^{17} \frac{K_i}{\varepsilon_i}.$$

Expenses of the passenger $C_{pas}$ determined by the time, the trip chosen route $\tau_0$, sometimes waiting for a vehicle $\tau$ and the cost of passenger hours $H$, characterizing financial time passenger as the average cost of wages for 1 hour in this region:

$$C_{pas} = K_1 NH \varepsilon_1 (\tau_1 + \tau_0).$$

Then the aggregate costs $C$ carrier and the passenger for 1 hour ($C = C_{car} + C_{pas}$):

$$C = \frac{K_1 NS}{\varepsilon_1} + K_1 NH \varepsilon_1 (\tau_1 + \tau_0)$$

$$= \frac{1 \cdot NS}{\tau_1 \frac{P_1}{\frac{1}{\tau_1} N}} + \frac{1}{\tau_1} NH \frac{P_1}{\frac{1}{\tau} N} (\tau_1 + \tau_0) \quad (2)$$

$$= \frac{N^2 S}{P_1 \tau^2} + HP_1 (\tau_1 + \tau_0).$$

find the best driving vehicles on the route $\tau_i$, to explore the function of (2) on the extremum is relatively $\tau_i$ to do this find the derivative $\frac{dC}{d\tau_i}$ we liken it to zero:

$$\frac{dC}{d\tau_i} = -\frac{2NS^2}{P_i \tau_i^3} + HP_i = 0,$$

$$\tau_i = \sqrt[3]{\frac{2NS^2}{P_i^2 H}}. \quad (3)$$

## V. Conclusions

Find the model of optimal interval movement of vehicles on the route (3) that simultaneously satisfies the economic interests of the carrier and the passenger. Application of information technologies allows to take into account the non stationarity of the demand for transport services in the region and the nature of the development of passenger-vehicle interactions, contributes to the development of measures aimed at optimizing the resource management, information and financial flows in the region. The authors found the optimum spacing of buses on the route. In further research it is used to optimize the profit of TE.

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**М. Г.Медведєв, Л. М.Олещенко. Інформаційні технології в організації міжміських автобусних пасажирських перевезень**

Проаналізовано проблеми інформаційного забезпечення організації роботи рухомого складу автотранспортних підприємств Чернігівщини. Знайдено оптимальний інтервал руху транспортних засобів для міжміських автобусних перевезень, що одночасно враховує економічні інтереси перевізників і пасажирів.

**Ключові слова:** інформаційні технології; автотранспортне підприємство; пасажирські перевезення; рухомий склад; інтервал руху; оптимізація; пасажиропотік; математична модель.

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**Н. Г. Медведев, Л. М. Олещенко. Информационные технологии в организации междугородных автобусных пассажирских перевозок**

Проанализированы проблемы информационного обеспечения организации работы подвижного состава автотранспортных предприятий Черниговщины. Найден оптимальный интервал движения транспортных средств для междугородных автобусных перевозок, что одновременно учитывает экономические интересы перевозчиков и пассажиров.

**Ключевые слова:** информационные технологии; автотранспортное предприятие; пассажирские перевозки; подвижной состав; интервал движения; оптимизация; пассажиропоток; математическая модель.

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