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The transport forecast – an important stage of transport management

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Abstract. The transport system is a powerful system with varying loads in operation coming from changes in freight and passenger traffic in different time periods. The variations are due to the specific conditions of organization and development of socio-economic activities. The causes of varying loads can be included in three groups: economic, technical and organizational. The assessing of transport demand variability leads to proper forecast and development of the transport system, knowing that the market price is determined on equilibrium between supply and demand. The reduction of transport demand variability through different technical solutions, organizational, administrative, legislative leads to an increase in the efficiency and effectiveness of transport. The paper presents a new way of assessing the future needs of transport through dynamic series. Both researchers and practitioners in transport planning can benefit from the research results. This paper aims to analyze in an original approach how a good transport forecast can lead to a better management in transport, with significant effects on transport demand full meeting in quality terms. The case study shows how dynamic series of statistics can be used to identify the size of future demand addressed to the transport system.

1. Introduction

Transport management is differentiated from industrial management by the fact that the system is subject to variable demands over time which can often not be accurately predicted and as such, satisfying the demand for transport can be quantitatively and qualitatively affected.

The specificity of socio-economic activities leads to a demand for transport that has different time attributes and manifests itself differently in time and space. The non-uniformity of traffic over time has many causes. Traffic peaks in freight transport can be identified in agricultural campaigns and traffic peaks in passenger transport can be identified during holidays, legal holidays, cultural, sporting, religious events or at different intervals of the day, etc.

Non-uniformity over time leads to difficulties in scheduling the park of vehicles to satisfy all transport demands. If the traffic would be uniform, forecasting and scheduling would be extremely easy for programmers and decision makers in transport. As this does not happen, it is attempted to optimize the programming so as to meet the schedule with a minimum vehicle park and a minimum number of board staff, taking into consideration some restrictions, both for vehicles and staff [1].

Non-uniformity over time can be *seasonal, daily and hourly* [2]. Ensuring traffic uniformity is based on the results obtained in previous periods, by pertinent traffic forecasts that are as accurate as possible to the values of the regression indicators.



To study the effects of the causes of the non-uniformity of transport, it is necessary to group them into categories. Starting from this criterion, the causes that produce variable exploitation demands were classified as economic, technical and organizational [3]. Economic causes have as a source the variation in the volume of traffic due to the increase in the income of the population and the share of free time, the seasonal nature of the holiday periods, or the change in the links between the travel's origin and destination areas. Technical causes have as a source the variations of traffic currents, both in size and rhythm, on shipment from point of origin or from intermodal nodes. Organizational causes result from non-uniformities due to discontinuous working regime of economical agents or due to interruptions in traffic.

Non-uniformity of freight and passenger transport influences all aspects of the foresight and planning activity of operators in the field. Above all, the unevenness of transport has a considerable influence on the level of the offered transport capacity level. The correct assessment of the size of the required transport capacity lies at the basis of the design of all the necessary constructions and facilities, and therefore the volume of investments and the deadlines for their recovery depend on it.

In order to solve the problems related to the size of the technical equipment of the transport operators and the improvement of the technologies, it is necessary to ensure the correlation between the tasks and the possibilities, namely between the effective and the maximum capacity, for which the total operating expenses are minimal.

On the transport market the level of traffic is set to the balance between transport offer and transport demand [4]. From the transport system – activity system interaction, the resulted traffic is characterized by the volume V_0 and the level of the quality of the insured services, t_0 (travel time), determined as solutions of the equilibrium between the offer (curve marked with O) and demand (curve marked with D), as shown in figure 1.

The decision to improve the transport system changes the transport offer from O_0 to O_1 (fig. 1), so there is an increase in the volume of traffic in the system $\Delta V = V_1 - V_0$, called *induced traffic*. Most often, the change of the offer from O_0 in O_1 leads to a service quality level t_1 lower than the anticipated t_0 , in the hypothesis that traffic is maintained at the same level.

Improving the transport system by moving the offer curve from O_0 to O_1 , stimulates the travel demand whose curve is transferred from D_0 to D_1 (fig. 1). The equilibrium traffic C_2 corresponds to a travel time $t_2 < t_0$, which can stimulate the demand for transport. The new equilibrium (t_3, v_3) with $t_3 > t_0$ is no longer able to stimulate the further growth of transport demand.

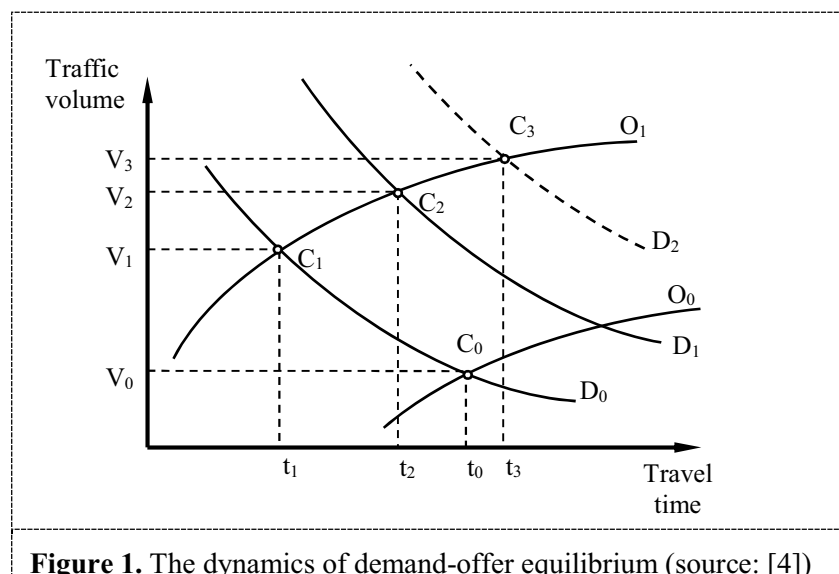


Figure 1. The dynamics of demand-offer equilibrium (source: [4])

From the situation presented in figure 1, there is a dynamic of the equilibrium between transport demand and transport offer, which has both positive and negative effects. The positive effects result from the continuous take-overs of new transport tasks, and the negative ones due to the externalities

caused by the worsening of the land use and all the undesirable effects that result from the proliferation of traffic [4, 5].

The transport and traffic forecast, as the initial stage of transport management, must be able to capture all these moments of changing the dynamic supply-demand equilibrium so that the transport system is prepared to successfully cope with all these dynamics so that all demands addressed to it to be satisfied in superior quality conditions.

2. Aspects of transport forecast

The forecast is defined as estimating the evolution of processes and future phenomena, the positive and negative effects they can generate on the managed system as well as the different strategies and scenarios of action for minimizing risks and maximizing the degree of achievement of the pursued objectives [6]. The forecast is made through diagnostic, forecasting and planning techniques.

The forecast models can be framed, as well as management types, over how long the concepts are achievable with great probability, in: strategic, tactical, and operative. Planning, as a management function (in English managerial literature, the foresight function is presented under the name of Planning), has been distorted in the centralized command economy, in which the essential relationships between the sectors of the economy and the functioning of the market was neglected, by neglecting the supply and demand law and by quasi-total elimination of the economic competition [7]. In the field of transport, abandoning planning was equivalent to limiting the state intervention in the field, which led to a fierce competition of the transport modes in both road and rail transport. The lack of regulation, and especially the lack of coherence in the applied pricing, has led from the complementarity of transport modes to competition, even where the areas of interest and competence clearly belong to one mode of transport.

The forecast, as a function of management, consists in the continuous attempt of building a more realistic picture of the future that corresponds to the achievement of the proposed objectives of the management. The degree to which the prefabricated future becomes reality is the true confirmation of the quality of the exercise of the foresight function.

The foresight function in transport is equivalent to how the system needs to be prepared to meet the demands of the society in terms of quantity and quality. This is a problem of balance in the context of a permanent dynamic of supply and demand that must constantly adapt to the formulated demands. Knowing the socio-economic evolutions can lead to economic sizing of transport system's constructions and installations to satisfy the demand with minimal resource consumption. It is known that the greatest waste of resources is encountered in transportation, whether due to internal causes that are not sufficiently studied (management of empty vehicles, systemic incompatibilities, geographic separation requiring different transshipment / gauge, correlation of schedules, interdependence in traffic charts, etc.), or due to external causes and environmental influences (goods that are not on time, non-respecting the schedules, unfavourable weather conditions, quantities of goods not in line with initial planning etc.).

The necessary data in the forecast are data regarding the evolution of the system and the factors that determined it. The used methods are those specific to statistical analysis, in uncertainty conditions, which allow to establish probable areas of values of some indicators, based on dynamic series analysis, regression analysis etc. [7]. Unfortunately, there is no way to determine by objective calculation the type of curve that best approximates the dynamic series available [8]:

The choice of the type of function that most accurately describes the known values is made by the curve aspect obtained by graphic representation of the observed values taking the time on the abscissa. After choosing the function, its coefficients are calculated by the least squares method called the regression method.

The chosen theoretical curve best describes the observed values when the sum of squares of the differences between the observed values and the calculated theoretical values is minimal. But the sum is minimal when the first derivative is zero, so, by doing the partial derivatives with respect to each of the unknown parameters, a system of equations from which these parameters can be calculated is obtained. The right to use the least squares method is demonstrated by the principle of maximum verisimilitude from probability theory.

Thus, for the case of the linear distribution having the form $y = a_0 + a_1 t$, the value of the model coefficients is calculated with the relations [9, 10]:

$$a_0 = \frac{\sum_{i=1}^m y_i}{m} \quad \text{and} \quad a_1 = \frac{\sum_{i=1}^m t_i y_i}{\sum_{i=1}^m t_i^2} \quad (1)$$

and for the case of the parabolic distribution having the form $y = a_0 + a_1 t + a_2 t^2$ the coefficients of the model are calculated with the relations:

$$a_0 = \frac{\sum_{i=1}^m t_i^4 \sum_{i=1}^m y_i - \sum_{i=1}^m t_i^2 \sum_{i=1}^m t_i^2 y_i}{m \sum_{i=1}^m t_i^4 - \left(\sum_{i=1}^m t_i^2 \right)^2}; \quad a_2 = \frac{m \sum_{i=1}^m t_i^2 y_i - \sum_{i=1}^m t_i^2 \sum_{i=1}^m y_i}{m \sum_{i=1}^m t_i^4 - \left(\sum_{i=1}^m t_i^2 \right)^2} \quad (2)$$

with the observation that the expression of the coefficient a_1 is the same as in the linear model and the relations are valid for the case where the origin of the time is chosen so that the relation $\sum_{i=1}^m t_i = 0$ is true.

The measure of the intensity of the link between the y_i and t_i is given by the correlation coefficient (r) for the linear model and by the correlation ratio (η) for the parabolic model.

$$r = \frac{m \sum_{i=1}^m t_i y_i}{\sqrt{m \sum_{i=1}^m t_i^2 \left[m \sum_{i=1}^m y_i^2 - \left(\sum_{i=1}^m y_i \right)^2 \right]}}; \quad \eta = \sqrt{1 - \frac{\sum_{i=1}^m (y_i - y^*)^2}{\sum_{i=1}^m (y_i - \bar{y})^2}} \quad (3)$$

where y_i represent the observed values; y^* – values calculated by the adjustment function; \bar{y} – the average of observed values.

The exponential model can be written as a linear model by logarithm.

$$\ln y = \ln a + bt \quad (4)$$

We note $\ln y = Y$; $\ln a = A$; $b = B$ and we obtain:

$$Y = A + Bt \quad (5)$$

$\sum_{i=1}^m t_i = 0$ and the coefficients a and b are calculated with the expressions:

$$\ln a = \frac{\sum_{i=1}^m \ln y_i}{m} \Rightarrow a = e^{\frac{\sum_{i=1}^m \ln y_i}{m}}; \quad b = \frac{\sum_{i=1}^m t_i \ln y_i}{\sum_{i=1}^m t_i^2} \quad (6)$$

The quality of the exponential model adjustment is given, as in the parabolic model, by the correlation ratio η .

Another model used for forecasts is the logistic one also called the *Pearl Reed* curve. The logistic model has the expression [11, 12]:

$$y = \frac{a}{1 + be^{-ct}} \tag{7}$$

having the coefficients a , b and c fulfilling the condition $a, b, c > 0$. The value a is assimilated to the saturation limit. The model is used in the study of the evolution of the population, in estimating the demand for durable goods, in ecology, in vehicle fleet evolution, and in general, in modelling phenomena that have a saturation limit over time (fig. 2).

Figure 2 shows that the logistics function is always positive and monotonous ascending. Parameters a , b , and c of the logistic curve are calculated according to the rule from Table 1 and to the condition $y_1 < y_2 < y_3$, if three points in the equidistant dynamic series are known.

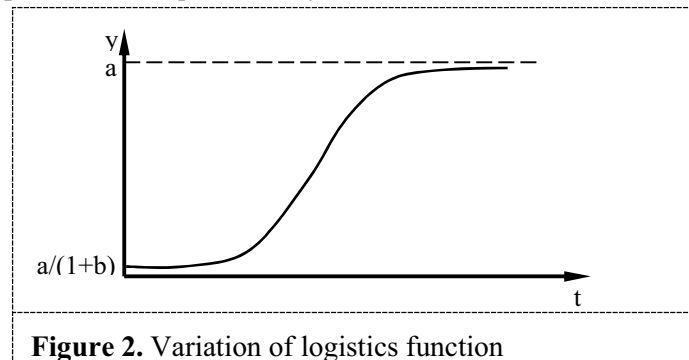


Figure 2. Variation of logistics function

In Table 1, t is the number of values in the dynamic series that separates two consecutive values as y_i . It is recommended that the y_i values to be chosen so that y_3 is the last value in the chronological series and y_1 is as close as possible in time to the first value of the series.

Table 1. The necessary conditions for determining the parameters of the logistic function

t	0	t	$2t$
y	y_1	y_2	y_3

The coefficients from the function of the forecasting model (a , b and c) are determined with the relations:

$$a = \frac{2y_1y_2y_3 - y_2^2(y_1 + y_3)}{y_1y_3 - y_2^2}; \quad b = \frac{a - y_1}{y_1}; \quad c = \frac{1}{t} \ln \frac{y_2(a - y_1)}{y_1(a - y_2)} \tag{8}$$

Another model used for forecasts is the production function model. The most known model is the one proposed by R. Cobb and P. Douglas [13], which has the form:

$$Q = a M^\alpha F^\beta r \tag{9}$$

where: a , α and β are the parameters of the model; Q – production volume; M – the volume of labour; F – the volume of fixed assets; R – residue of estimation as an average of the differences between recorded and calculated values.

The calculation of function parameters is made by logging the expression that defines it and then by the least squares method the searched values are obtained.

$$\ln Q = \ln a + \alpha \ln M + \beta \ln F \tag{10}$$

$$\text{We note: } \ln Q = q, \ln a = A, \ln M = t \text{ și } \ln F = f \tag{11}$$

Using the least squares method we obtain:

$$\begin{cases} \sum_{i=1}^m q_i = mA + \alpha \sum_{i=1}^m t_i + \beta \sum_{i=1}^m f_i \\ \sum_{i=1}^m t_i q_i = A \sum_{i=1}^m t_i + \alpha \sum_{i=1}^m t_i^2 + \beta \sum_{i=1}^m t_i f_i \\ \sum_{i=1}^m f_i q_i = A \sum_{i=1}^m f_i + \alpha \sum_{i=1}^m t_i f_i + \beta \sum_{i=1}^m f_i^2 \end{cases} \quad (12)$$

Evolution models based on extrapolation of the trend can be used for short and medium term forecasts. Each time it is mandatory to estimate the probable error by attaching to the forecast a confidence interval and a threshold of significance as to any other statistical approach.

3. Case study

The evolution in time of the volume of goods transported for a certain transport relationship is known (table 2).

Table 2. Evolution of the volume of transported goods

Year	2009	2010	2011	2012	2013	2014	2015	2016
Quantity × 10 ³ [t]	142	150	158	162	165	177	190	202

Considering that the evolution of the socio-economic factors will be preserved in the next forecasting period, the most appropriate expression should be established which will approximate in the future the present values of the volumes of transported goods. Parameters of linear, parabolic, exponential and logistic models are determined for this. These models were chosen because the time evolution of the data follows an ascending curve. The necessary elements for calculating the parameters of the linear and parabolic model are presented in Table 3.

For the linear model, a_0 , a_1 and r are determined using the equations (1) and (3). The obtained values are: $a_0 = 168,25$; $a_1 = 4,05$ si $r = 0,980063$.

For the parabolic model a_0 , a_1 , a_2 and η are determined using the equations (1), (2) and (3). The obtained values are: $a_0 = 164,875$; $a_1 = 4,05$; $a_2 = 0,1607$; $\eta = 0,992347$. It is noticed that $\eta > r$ which leads to the conclusion that the parabolic model approximates better the given values.

Table 3 The required elements to calculate the parameters of the linear and parabolic model

t_i	y_i	t_i^2	$t_i y_i$	y_i^2	t_i^4	$t_i^2 y_i$	y_i^*	$(y_i - y_i^*)^2$	$(y_i - \bar{y})^2$
-7	142	49	-994	20164	2401	6958	144,40	5,76	689,06
-5	150	25	-750	22500	625	3750	148,64	1,84	333,06
-3	158	9	-474	24964	81	1422	154,17	14,66	105,06
-1	162	1	-162	26244	1	162	160,99	1,03	39,06
1	165	1	165	27225	1	165	169,09	16,69	10,56
3	177	9	531	31329	81	1593	178,47	2,16	76,56
5	190	25	950	36100	625	4750	189,14	0,74	473,06
7	202	49	1414	40804	2401	9898	201,10	0,81	1139,06
Σ	1346	168	680	229330	6216	28698	1346,00	43,69	2865,5

However, the linear model also offers a good approximation, since the value of the correlation coefficient is very close to the unit. The elements required for calculating the exponential model parameters are shown in Table 4.

Table 4 The elements required for calculating the exponential model parameters

t_i	y_i	t_i^2	$\ln y$	$t_i \ln y_i$	y_i^*	$y_i - y_i^*$	$(y_i - y_i^*)^2$	$y_i - \bar{y}$	$(y_i - \bar{y})^2$
-7	142	49	4,956	-34,691	141,074	0,926	0,858	-26,25	689,063
-5	150	25	5,011	-25,053	148,007	1,993	3,970	-18,25	333,063
-3	158	9	5,063	-15,188	155,282	2,718	7,387	-10,25	105,063
-1	162	1	5,088	-5,088	162,914	-0,914	0,836	-6,25	39,063
1	165	1	5,106	5,106	170,922	-5,922	35,066	-3,25	10,563
3	177	9	5,176	15,528	179,323	-2,323	5,394	8,75	76,563
5	190	25	5,247	26,235	188,136	1,864	3,473	21,75	473,063
7	202	49	5,308	37,158	197,383	4,617	21,313	33,75	1139,063
Σ	1346	168	40,954	4,008	1343,042	2,958	78,298	0,00	2865,500

For the exponential model, a , b and η are determined using the equations (6) and (3).

The values $a = 166,87$; $b = 0,023857$ si $\eta = 0,986243$ are obtained. The function is $y = a e^{bt} \Rightarrow y = 166,87 \cdot e^{0,024t}$.

The attempt to model the data in Table 2 through a logistic function fails because, for the coefficients in the function of the forecasting model (a , b , c), we obtain the values: $a = 135,22$; $b = -0,09854$; $c = -0,20174$, values that cannot represent a pertinent logistic function because both for b and for c , negative values have been obtained.

Table 5 shows the evolution of the park of vehicles in circulation for eight consecutive years.

Table 5 The evolution of the park of vehicles

t_i	-1	0	1	2	3	4	5	6
y_i	70	76	84	92	107	116	130	144

Using the values from Table 5, where the origin of time was established, the parameters a , b and c of the logistic model are determined. The values that are chosen are $y_3 = 144$, $y_2 = 107$ si $y_1 = 76$, for $t = 3$. For the logistic model we determine a , b and c using the equation (8). The obtained values are: $a = 350,028$; $b = 3,61$ and $c = 0,154$. The logistics function is defined as follows: $y = \frac{350,028}{1 + 3,61 e^{-0,154t}}$

The asymptomatic tendency towards a value is demonstrated using the data listed in table 6.

Table 6 Future values of the series obtained with the logistics function

t_i	40	45	50	60	70	80	90	100
y_i	347,38	348,80	349,46	349,91	350,01	350,024	350,026	350,028

Table 6 shows that series values are asymptotically approaching the value of a ($a = 350,028$) and beyond the value $t = 70$, the increases are insignificant.

Table 7 shows the differences between the recorded values and those approximated by the logistics function.

Table 7 The known values of the series determined using the logistics function

t_i	-1	0	1	2	3	4	5	6
y_i	70	76	84	92	107	116	130	144
y_i^{cal}	67,17	75,92	85,48	95,81	106,89	118,65	131,02	143,87
$\frac{y_i^{cal} - y_i}{y_i} \cdot 100$	-4,28	-0,11	1,76	4,14	-0,10	2,28	0,708	-0,09

Table 7 shows that the differences between the known values of the series and those approximated by the logistic function are between - 4,28% and -0,09% as negative values and 4,14% and 0,78% as positive values. So, both positive and negative differences are below the $\pm 5\%$ threshold.

4. Conclusions

The relatively rapid variations of the demand, both in size and structure, addressed to the transport system, lead to the need of knowing with anticipation and security the future developments. Eliminating or reducing traffic non-uniformities is an essential task for transport planners and decision-makers from all levels involved in the socio-economic activity that generates travel needs. Through these actions, the temporal variations of the demand will be known and the transport system will be prepared to meet the demands in conditions of safety, security and quality.

The paper presented the most known predictive models (polynomial, exponential, logarithmic, trigonometric polynomial, Cobb Douglas and logistic model) and carried out a case study for real transport data.

The presented models are useful in forming an image of the future evolution of the systems, but the expected results must be carefully considered and analysed, considering that one of the conditions of application is the preservation of present and future socio-economic conditions. This is the main criticism of the prediction models - *the fact that the past is prolonging in the future* - which makes them vulnerable to changes in the external environment of the analysed system.

Unlike the exponential adjustment model, which grows infinitely, the logistic model has a finite growth. This curve is important because it models the transport growth, many of which have finite growths.

Example: increased traffic with a finite limit dictated by the capacity of existing or even designed arteries and parking facilities. The increase in the volume of goods transported in any of the transport systems also has a limit: the increase in vehicle park or, more recently, dependence of the speed of density in traffic flow theory. There is even a reverse logistic function that has asymptotes at the top and bottom, known as the speed, even in free flow mode and has finite values.

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