*Proceedings of the 10th International Conference "Reliability and Statistics in Transportation and Communication" (RelStat'10), 20–23 October 2010, Riga, Latvia, p. 60-65. ISBN 978-9984-818-34-4*
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# THE DESCRIPTION OF THE DYNAMIC TRANSPORTATION MODEL IN THE TERMS OF EFFICIENCY MEASURES

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In this work there is proposed the description of the dynamic model for the cargo transportation process. This model is represented by the set of mathematically related functionals that describe physical operations and actions with the cargo during the transportation process from the sender to the receiving point. For assessing the efficiency measures by specified conditions it is needed to describe every functional in terms of the taken measure (for example, with respect to the reliability of delivery, speed of delivery, delivery time etc.). The described measures are not directly related to the cost parameters of the transport services.

Unfortunately, the description of every functional in the dynamic cargo transportation model in accordance with the specified direct measure is not always possible. But still the problem of objective and reliable assessment of the effectiveness of the transportation process is one of the most pressing and difficult. The solution of the problem makes possible to evaluate the efficiency of the cargo transportation process, as well as to optimise the entire process according to the selected measure.

In the work, it is offered to describe the dynamic model of the cargo transportation process in terms of the indirect measure of the reliability of transportation, namely – "safe" travel time, as well as options for its use.

***Keywords:*** *transportation, dynamic model, efficiency measure*

## 1. Introduction

In recent years there are different kind of models have been used for the assessment of the effectiveness of the transportation process. The aim of those models is to define the quantitative measure characterizing the system ability to satisfy the requirements assigned to it.

Usually the description of transportation process leads to the definition of some coefficients of loses in static models. These coefficients of losses influence the assessment of the transportation quality, in general. Its significance cannot be overstated or reduced as all the coefficients should be balanced as well. Furthermore, the choice of the coefficients should be subjective and it is so, as for the specific road the coefficients should be different.

In the work by Vrubel Y.A., Kapsky D.V. and Kot E.N. [1], there is the assessment of the effectiveness of the transportation process leading to some costs examined and consists of the aggregated loss of following aspects: safety, environment, profitability, sociological, reliability, productivity and comfort. The summary document of Transport Research Center of the OECD and the International Transport Forum [2], proposes to evaluate the effectiveness of the transportation process as the travel time reliability where the temporal journey time improvement should be split into pure journey time improvement and buffer time (or other temporal reliability measure) improvement for each granulation. The change in time savings benefit then equals the change in pure journey time multiplied by monetary value of time, plus the change in buffer time multiplied by monetary value of reliability.

In the static models there are exist following procedure for defining the coefficients (that characterizes defined losses) for the certain road segment. First of all, there are the measurements of road characteristics are made. Then, the distribution law should be obtained as well as some statistical characteristic from that distribution law should be found. Thus the identified characteristic is accepted as the coefficient. The described procedure is laborious and takes a lot of time. In the same time, it is subjective as all the measurements are made in the certain period of time, for the specific road segment etc.

The dynamic models are often devoted to the solution of pickup and delivery problems – the class of vehicle routing problems in which objects or people have to be transported between an origin and a destination, for example, in survey paper of Berbeglia G., Cordeau J.-F., Laporte G. [3]. In the work of Savelsberg M.W.P. and Sol M. [4], the main idea of general pickup and delivery problem is the set of

routes to be constructed in order to satisfy transportation request. In a dynamic situation (when some of the requests are known at the time the routes have to be constructed and the other requests become available in real time during execution of the routes), at the time when a new transportation request becomes available, at least one route has to be changed in order to serve this new request. But in practice, the dynamic pickup and delivery problem is often solved as a sequence of static problems, like: each time a new request for service is received, a slightly modified instance of the static problem is solved to update the current route.

In this work, there is presented the dynamic cargo transportation model that suggests not to obtain and calculate the statistical characteristics of the taken measures, but to take functions, that are related to the corresponding distribution laws of random parameters and to use them in the model [5].

An adequate model should allow making the composite equation that describes the cargo transportation system with respect to any quantitative measure of the effectiveness of cargo transportation process.

Unfortunately, the description of every functional in the dynamic cargo transportation model in accordance with the specified direct measure is not always possible. In the work, it is offered to describe the dynamic model of the cargo transportation process in terms of the indirect measure of the reliability of transportation, namely – “safe” travel time, as well as options for its use.

## 2. The Description of the Dynamic Cargo Transportation Model

As the cargo transportation process there is the consecution of the actions and technological procedures that provide the cargo carriage from the sender to the receiving point, will be taken. So, from the perspective of transported object (cargo), the transportation process could be presented as follows (Figure 1):

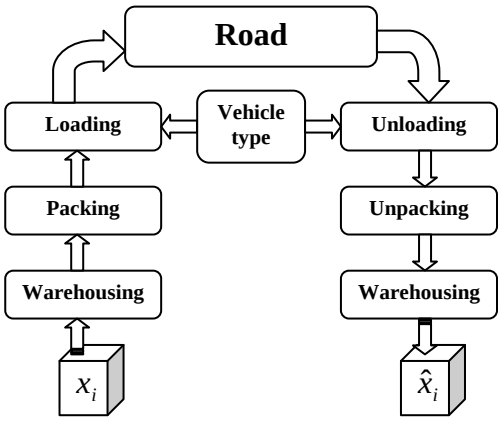


*Figure.1.* The scheme of the of cargo transportation process

where:

$x_i$ – shipped (initial) cargo,

$\hat{x}_i$ – cargo after the transportation process,

$i$ – type of cargo.

Conditionally, such consecution of the cargo transportation process could be divided into three main parts and represented by following operators that mathematically describing physical operations and actions with the cargo during the transportation process:

The set of operations that describes the way the cargo is sent (1):

$$\{s_i\} = D_{sent}\{S, x_i\} = D_{load}\{D_{pack} D_{whs}\{x_i\}, S\}, \tag{1}$$

where: $x_i$ – (initial) cargo,

$i$ – type of cargo,

$S$ – mode of transport,

$D_{sent}$ – operator of shipping method,

$D_{load}$ – operator of loading method,

$D_{pack}$ – operator of packaging method,

$D_{whs}$ – operator of cargo storage and warehousingmethod.

The set of operations that describes the influence of the road on the cargo transportation process (2):

$$\{\hat{s}_i\} = D_{road}\{S, x_i\} = D_{road} D_{sent}\{S, x_i\}, \tag{2}$$

where: $D_{road}$ – operator of road properties.

The set of operations that describes the way the cargo is received (3):

$$\{\hat{x}_i\} = D_{receive}\{S, x_i\} = D_{unload} D_{unpack} D_{whs}\{S, x_i\}, \tag{3}$$

where: $\hat{x}_i$ – cargo at the destination point;

$D_{receive}$ – operator of cargo receiving method;

$D_{unload} D_{unpack} D_{whs}$ – operators of unloading, unpacking and warehousing methods accordingly.

Taking into account all the operations shown above (methods of cargo shipping, receiving and influence of the road), the whole cargo transportation process could be also described in the operator form (4):

$$\{\hat{x}_i\} = D_{receive}\left[D_{road} D_{sent}\{S, x_i\}\right]. \tag{4}$$

It is also could be rewritten taking into account the sense of the certain operators in the following way (5):

$$\{\hat{x}_i\} = D_{unload} D_{unpack} D_{whs}\left[D_{road} D_{load}\left\{D_{pack} D_{whs}\{x_i\}, S\right\}\right]. \tag{5}$$

The advised approach allows describing the cargo transportation process with the help of mathematical model. As well as it makes possible to set the problems of the cargo transportation processes optimisation and to find the ways the problems could be solved [1].

The main task of the cargo transportation process is to deliver the cargo (taken multitude $\{\hat{x}_i\}$) to the destination point in the condition that is close to the initial one $\{x_i\}$, where the quality of the cargo transportation process is defined by the described degree of the cargo state approximation.

In the modern applications there are the most-used criteria – the assessment of the cargo transportation process by the value of charges (costs) for the transportation of one cargo amount under the desired transportation quality. Those criteria could be named as cost per unit criteria. And, according to them, the best system is the system with lower unit costs.

The unit costs could be easily and uniquely counted for the cargo shipping and receiving methods' procedures. But the great variety of roads, highways, as well as the interaction features of vehicles on them, as usual, doesn't allow defining appropriate costs during the vehicles travel time.

The described measures in this work are not directly related to the cost parameters of the transport services. Since, in the general understanding the assessment of the cargo transportation process is rather subjective. It is known that the profitable cargo transportation is the transportation that pays for itself entirely and brings some profit. But the development and the progress levels will differ in every country in general, and in every transport company, particularly. So, the achieved goals of every company will be different and it is hard to compare. Therefore, in this work the assessment of the effectiveness of the cargo transportation process was made in respect of the time spent for the cargo transportation, instead of the transportation costs.

## 3. The Model Description in the Terms of the Safe Travel Time

In this paper, it was taken, that all packing/unpacking procedures as well as all cargo shipping ($D_{sent}$) and receiving ($D_{reseive}$) operations are realized ideally. In this case, there is the process of haulage ($D_{road}$) that has the greatest influence on the cargo transportation process, in general. Indeed, it happens because the biggest part of logistic operations (on the way of the material flow from the initial source of supply to the final customer) is performed by different modes of vehicles. These logistic operations can make till 50% from the sum of the logistics costs in total [6]. So, visualizing the cargo transportation process according the stated above ideal conditions, we will have (Fig.2):

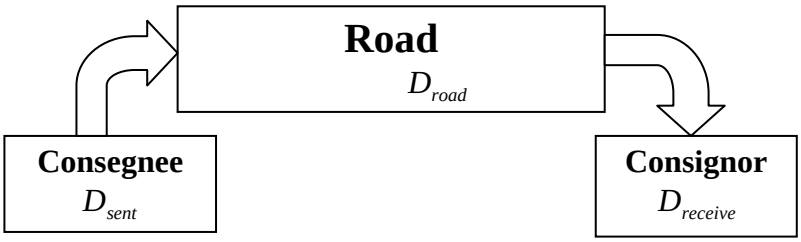


*Figure 2.* The cargo transportation process under taken ideal conditions

Any type of road has the following properties and the influence on the vehicles during the travel time, independently of its construction type:

- Some energy consumption needed to overcome the road;
- Some time consumption, needed to overcome the road.

From the point of view of vehicle ($S$), the described energy and time consumptions are tightly linked. But, from the point of view of the cargo ($x_i$), the main criterion is time consumption, i.e. the travel time.

Hence, it could be taken that the influence of the road on the cargo transportation process ($D_{road}\{S, x_i\}$) – this is a functional, that:

a) Describes time and energy consumption of the road vehicle during the travel time

b) Defines, in the limit, the potential facilities of delivery time for the road, depending on the category of the road, road lanes amount on it etc.

In this case, any violation of the road properties, in relation to its' potential facilities, play role of the deterioration factor of the cargo condition during the travel time. The deterioration factors always exist, despite of other vehicles' amount presence on the same road and their behaviour on it. Consequently, the presence of other vehicles complicates the described functional significantly.

The interaction between the vehicles on the road is not an additive one. Thus, the process of the vehicles interrelation is a very difficult task and needs to be solved due to mentioned above factors.

Let's consider the set of operations that describes the road influence on the cargo transportation process in details. In this work, there is the vehicle travelling with a cargo on the road that consists of some segments with changing traffic conditions, such as: speed, number of lanes of the road, number of passing and oncoming vehicles, etc. Initially, the road is divided into two main types of segments (Figure 3) with initial appropriate conditions (speed allowance, number of pedestrian crossings, number of controlled and non-controlled crossing, etc.):

I – road segment in the built-up area

II – road segment between the built-up areas / outside the built-up areas

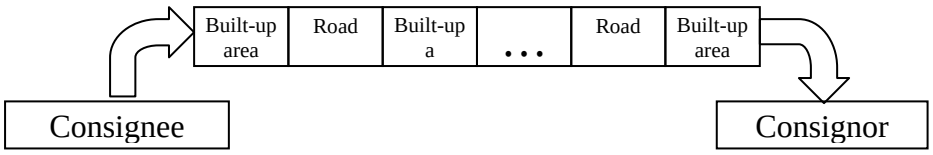


*Figure 3.* The cargo transportation process

So, the functional describing the road influence on the cargo transportation process will be presented as follows:

$$D_{road} = D\left(\Delta t_{i\_in} + \Delta t_{i\_out}\right), \tag{6}$$

where: $\Delta t_{i\_in}$ – time intervals when the road vehicle moves inside the built-up areas

$\Delta t_{i\_out}$ – the time intervals when the road vehicle moves outside the built-up areas

Taking into account all the initial conditions and the characteristics of the road segments, the time spent for the vehicle travelling inside the built-up areas will be equal to:

$$\Delta t_{i\_in} = D_1\left(n_{no\_cross}, n_{cross\_control}, n_{cross\_non-control}\right), \tag{7}$$

where: $n_{no\_cross}$ – amount of road segments between crossings,

$n_{cross\_control}$ – amount of controlled crossings

$n_{cross\_non-control}$ – amount of non-controlled crossings

The functional $D_1$ is characterized by the average coefficients that correspond to the travel time inside the built-up area and depend on amount of crossings (controlled and non-controlled) and amount of road segments between crossings. In the frames of this work, the influence of the functional $D_1$ on the total travel time is taken as the average coefficient for any type of built-up area.

In turn, the time spent for the vehicle travelling outside the built-up areas will be equal to:

$$\Delta t_{i\_out} = D_2\left(n_{cross}, n_{no\_cross}, n_{slow}, n_{pass}, n_{onc}\right), \tag{8}$$

where:

the functional $D_2$ is characterized by the parameters that are random variables and described by the relevant laws of distribution. Such parameters are:

- amount of slow-moving vehicles
- presence or absence of obstructions behind
- presence or absence of obstructions in front of the road vehicle
- presence or absence of obstructions in front of the next vehicle
- amount of vehicles in oncoming flow, etc.

According to the mentioned above description of the functionals inside and outside the built-up areas, the functional that mainly influences the road during the cargo transportation process, could be shown as follows:

$$D_{road} = \left(\left\langle \Delta t_{i\_in} \right\rangle, D_2\left(n_{cross}, n_{no\_cross}, n_{slow}, n_{pass}, n_{onc}\right)\right). \tag{9}$$

The usage of this model allows to get information about the total time spent on certain cargo transportation process taking into account possible variations of road conditions, as well as to compare it with the safe travel time (with the potential one)[7].

## 4. Conclusions

The described dynamic cargo transportation model in the terms of safe travel time allows getting the probabilistic estimates of the vehicle travel time. It makes possible to define potential facilities of the road for the travel time – the period of time that is calculated under the condition of the absence of any other vehicles neither passing nor oncoming – safe travel time:

$$D_{road} = \left(\left\langle \Delta t_{i\_in} \right\rangle, D_2\left(n_{cross}, n_{no\_cross}\right)\right). \tag{10}$$

Thus, any deviation from the vehicles' mode of motion, in relation to its' potential facilities plays role as the negative factors of the cargo transportation quality.

The described model allows to optimise the cargo transportation process by minimizing the travel time deviation from the potential one by choosing the vehicle type suitable for the given cargo type transportation.

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