ZESZYTY NAUKOWE WYŻSZEJ SZKOŁY TECHNICZNEJ W KATOWICACH
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PROBABILISTIC MODEL OF CALCULATING A RISK OF PLANNING ROUTES IN TELEMATICS SYSTEMS

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ABSTRACT

This paper aims to familiarize readers with notions related to probabilistic methods used for planning routes in telematics systems. The classification task made use of the model based on probabilistic Bayes' classifier and the probability density function. The first part of the paper describes problems with planning routing in contemporary telematics systems. The second part covers a theoretical basis of classifiers based on hard mathematical methods. If such a model is to make sense, it should account for smaller kinds of risk related to a transport process. This paper presents a method of selecting the most optimal parameters in transport planning. Its author draws attention to the variable reduction method necessary for planning supported by a factor analysis of principal components together with Varimax rotation normalized with Kaiser's method for quantitative features. The third part is devoted to the process of planning routes and the related risk.

KEYWORDS

transport planning, a factor analysis, evaluation of transport risk

INTRODUCTION

This paper aims to present a probabilistic model of evaluating a risk in planning routes in telematics systems. In order to fulfil this objective, fundamentals of probabilistic methods were presented including the law of total probability, Bayes' theorem as well as the notion of probability distribution. The author draws attention to the issue of contemporary telematics systems related to the quality of their operation. This quality is strictly tied up to a growing number of input variables to be analysed by the system for the purposes of making the best decision. Some of these features may turn out to be strongly related to each other and it may not make sense to analyse them separately as an independent predicator. Thus a model of reducing quantitative factors was proposed supported by the factor analysis method of principal components with normalized Varimax rotation.

1. RISK IN TELEMATICS SYSTEMS

When talking about risk in general, we may say that it is a factor of an event which may result in losses. It is strictly related to probability as it is proportional to the likelihood of occurrence of the above event or state as well as the size of losses we may incur.

The notion of risk may also refer to the probability of such event occurring to make us undertake additional actions resulting in using additional resources such as materials, services and also improve qualifications of employees if we employ them.

Transport involves moving cargo from one place to the other. Obviously, in commercial transport it is not only about transporting cargo. The main transport factors include: time, a quality and transport costs. These are factors strictly related to each other and in case of the price mutually dependent. In combination, they provide an evaluation of the service rendered. In order to deal with an overall evaluation of the service, firstly we need to discuss each factor separately.

Transport time covers a period from loading to unlading including transportation and all stops of random nature such as obstacles on the road, bad road conditions as well as those resulting from a transport schedule or legal regulations. It should be mentioned that transport time does not comprise waiting for loading and unloading. It may be divided into three main elements. Loading time, unloading time and driving (including all stops). All those components make up the final outcome of the service referred to as transport.

When evaluating transport time, we assume overall transport time as the main criterion (all three main elements). The sooner cargo is transported to a destination point the better (a better evaluation). Sometimes only two elements are taken into account – loading time and driving time or driving time and unloading time. In extreme situations we may evaluate the total transport time on the basis of driving time only. This applies to complicated loading and unloading instances, non-standard cargo: hazardous materials or over-sized cargo as well as specific places of loading and unloading. Summing up the evaluation of the time parameter of a transport service we should consider all possible transport problems, account for time reserves when planning and then start evaluation. The evaluation should be inversely proportional to time of completing the service, the shorter the time the better evaluation.

A transport cost is another equally important factor in transport affecting a quality as well as the evaluation of transport. In forwarding total costs directly influence transport rates. These costs are divided into three groups:

1. Operating costs
2. Financial costs
3. Other operating costs

The above costs are divided into fixed and variable, direct and indirect.

Direct costs include factors such as:

1. Depreciation of vehicles and equipment,
2. Consumption of petrol and consumables like tires, oil, lubricants etc.
3. Transport services like ferries, tolls, haulage,
4. Services: check-ups, technical examinations, repairs on the on-going basis
5. Salaries and insurance.

Other costs not directly related to transport services are included in overheads. Financial costs of a company entail costs of negative exchange rate differences as well as interest calculated on investment credit. Overdue taxes are also included in financial costs. Operating costs comprise financial provisions which are designated for carriers. In each service sector also in transport the quality of a service is evaluated. When it

comes to transport companies and forwarding companies a quality evaluation is strictly connected to the number of deliveries. Qualitative criteria in such a case comprise the following measurements:
1. On-time deliveries– understood as a percentage of deliveries meeting deadlines of a customer,
2. Completeness of deliveries – the percentage of complete and undamaged deliveries,
3. Completeness and correctness of documents' fulfillment,
4. The price – lower prices in case of regular orders on the yearly basis,

The other criteria of the qualitative and quantitative evaluation comprise qualitative measurements, namely:
- Detailed information about the cargo status,
- Communication with employees of a transport company or a forwarding company,
- Preventive and coordination methodology,
- Transparency of operation procedures

Based on the above factors, interdependencies between them and their occurrence in all completed operations we can see overall behaviour of employees which is translated into a widely understood quality of services rendered [4, 11]

Road transport is one of the easiest modes when it comes to moving and handling goods. It does not require a process complexity and it can deliver supplies to any place. Some transport areas mainly international require additional activities e.g. forwarding, logistic services. In Figure 1 presents a simple architecture of a transport system.

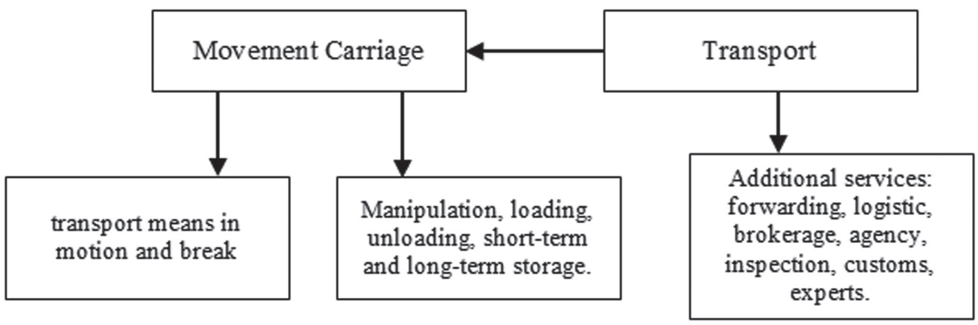

Fig. 1. A simple architecture of a transport system

Source: based on J. Neider, Transport międzynarodowy, PWE, Warsaw 2012, p. 12

Movement of goods cannot be done without participation of transport branches. According to the definition provided by Dr Aleksandry Koźlak „a transport process is a closed series of activities whose aim it is to efficiently move cargo".

A process of carrying also called transporting is a vital element of the transport process. It involves loading and unloading and moving goods actively and passively understood as all stops and workshops. One of the architectures of the transport system is presented in the elaboration [8]

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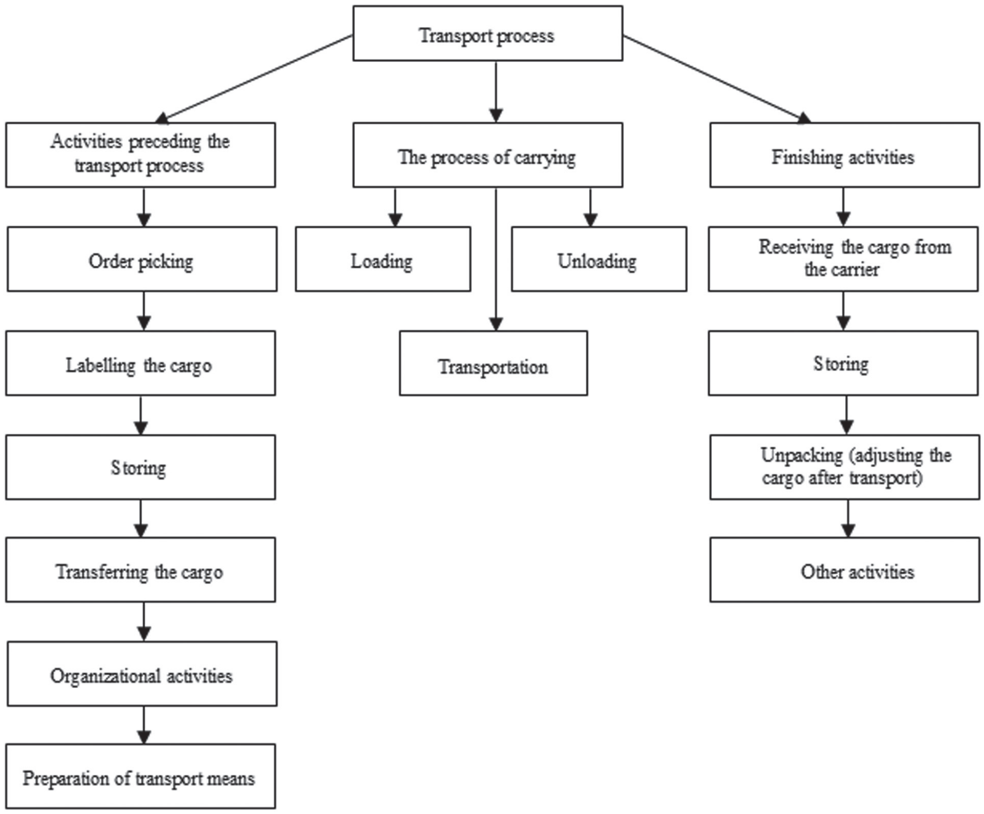

Fig. 2. Chart of the transport system

Source: A. Koźlak, Ekonomika transportu. Teoria i praktyka gospodarcza, Wydawnictwo Uniwersytetu Gdańskiego, Gdańsk 2008, p. 132.

Factors resulting from organization of carriage are at the beginning and the end of a transport process and also create this process. Movement of goods is included in a technological process of transport.

Its entirety is underlined by joint occurrence of the processes:

- Technological process of temporary warehousing with senders or recipients of goods as well as with transition warehouses,
- technological works of handling goods,
- technological process of multimodal transport.

The subject of transport, its direction or type of commercial contracts concluded reveals a variety of transport processes mainly when they are subject to international commercial agreements. In this case the transport process may be divided into the following stages:

- preparation of the course of movement,
- organization of goods for transport,
- preparing a carrying process,
- physical movement of cargo,
- handling the process in terms of legal and financial issues,
- measurement of costs and the evaluation of the course of the transport process.

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Transport should be considered from the system's point of view. The transport system constitutes "an orderly entirety of all branches of transport operating through an infrastructure on a specific area with a human factor, inter-branches ties within this entirety and connections of the entire transport system to the surroundings". The system consists of an active sub-system of means of transport. A passive one is constituted by transport connections, the size and location of cargo as well as the equipment enabling transport means to freely operate [12]

This is nothing else than determining spaces of elementary events. In other words we deal with establishing the probability of risk occurring and the extent of losses caused by this risk. We can use a theorem about conditional loss- just to remind: measuring the probability that event A provided that event B has occurred.

A strategic and operational risk must also be taken into account. The first one occurs in the long-term on yearly basis and the scope of its negative effects is wide. A strategic risk originates from making investment decisions, new technologies, production programmes and even political determinants. An operational risk as opposed to the strategic one occurs in the short-term and refers to current problems in the transport process. It is difficult to predict which makes building probabilistic models complicated and often incorrect but fortunately it is of little importance.

Building probabilistic models for establishing the probability of risk occurrence is based on considering possible failures and eliminating oversights. For example not paying attention to competitors who launched a similar product into the market may be an oversight.

Apart from the above strategic and operational risks, the evaluation of risk in the transport process takes into account the following risks:

- a market risk- caused by changes triggered by competitors. An entrepreneur finds out in the market whether their actions undertaken succeeded or failed. This risk is related to the purchase of equipment necessary for transport and sales of goods manufactured.
- A capital risk- concerns ways of financing an enterprise. It also refers to meeting deadlines for paying fees. The risk which arises here concerns the lack of financial liquidity. Entrepreneurs using banking assistance in the form of loans are most often exposed to such a risk.

In order to protect against consequences of a failure, the risk evaluation should also involve aspects related to a production risk:

- A material risk – concerns the equipment and technologies used in the transport process, the stocks and finished goods as well as goods in transport. This risk refers to a destruction, a damage, a theft which should be eliminated.
- A personal risk- refers to the technical and managerial personnel including the lack of qualifications.
- A risk of disrupting transport- causing losses in profits. To eliminate it a reliable transport should be made including deadlines for ordering supplies, finished goods or periodic check-ups of the equipment and software.
- A third party risk- related to paying damages in the event a damage is done due to production activities. It concerns a poor quality of products manufactured or a damage done to the environment.

2. A MODEL OF CALCULATING A RISK AND PLANNING TRANSPORT

In order to develop a model of a transport risk, a complete architecture of the telematics system must be familiarized with [6]. There are various methods of assessing a risk and analysing transport systems. Methods of variables' aggregation are particularly i.e. a cluster analysis discussed by this paper and a cluster analysis [7].

The transport task made use of a factor analysis method of principal components with Varimax rotation normalized by Kaiser's method. This way another model indicating most strongly related data was developed.

Most importantly the factor analysis assumes that if we have a large number of related features, the connections between them should result from the existence of a series of common factors which in turn will be connected to particular features of the analysed group. We can notice that the factor analysis is based on the hypothesis that in set *p* $\{X_i;$ $i = 1,2, \ldots, p\}$ there are factors hidden being the source of information contained in them.

For event A, where P(A) > 0 and a series of events
$B_1, B_2, \ldots, B_n$ meeting the following conditions:

1. $P(B_i) > 0\ for\ each\ i \in \{1,2,\ldots,n\}$
2. $B_i\ are\ disjoint\ pairs$
3. $B_1 \cup B_2 \cup \ldots \cup B_n = \Omega$

We may establish conditional probability that a break-down to a telematics system occurs for feature $X_{i\,i}$ provided that event A has occurred (resulting in given value X_i) expressed by the formula:

$$P(\mathrm{Xi}|A) = \frac{P(X\mathrm{i}) \cdot P(A|X\mathrm{i})}{P(A)} \qquad (1)$$

The research factor analysis aims to find factors in common (a new group of variables) being responsible for the behaviour of individual features of planning a transport route or particular sets of these features. Thus a factor analysis may also be applied to the search of groups of features similarly responding according to the established connection evaluations between these features, for example correlation coefficients. When looking for compatible factors we may assume that we most often use a correlation matrix (R) between selected features of the analysed set.

The most common method of determining factors is a principal component analysis consisting in assigning factor Z_j to an eigenvector for jth eigenvalue of the correlation matrix. The "discovered" factors are often interpreted in view of the contents. We should remember however that these are arbitrary values which allow us to mathematically describe the set which we examine. Nevertheless we should remember that the most frequently used method for separating principal components is constituted by the principal component analysis and the maximum likelihood method.

Let us remind that between factors Z_j $(j = 1,2, \ldots, q < p)$ and variables X_i linear connections occur for $i = 1,2, \ldots ,p$:

$$X_i = a_{i1}Z_{i1} + a_{i2}Z_{i2} + \cdots + a_{iq}Z_{iq} + b_iU_i = \sum_{j=1}^{q} a_{ij}Z_{ij} + b_iU_i\,, \qquad (2)$$

in the matrix notation:

$$X_{px1} = A_{pxq}Z_{qx1} + B_{pxp}U_{px1}, \text{ where } B = diag(b_1, b_2, \ldots, b_p),$$

Where a,b – parameters model and $A=\{a_1,a_2,\ldots,a_p\}$ and $B=\{b_1,b_2,\ldots,b_p\}$

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We call coefficient a_{ji} by a factor loading of factor Z_j (common factor) on the feature X_i (intensification of factor j in variable i). Variables U_i are considered as random variables, they are central and not correlated with each other. It means that correlation (Z_j ; Z_m) = 0. The *U* is an independent variable of the model. and correlation (U_j ; U_m) = 0 for j m and correlation (Z_j ; U_m) = 0 for j = 1,2, … ,q i m = 1,2, … ,p, where p and q is number of columns and rows of matrix. For such assumptions correlation matrix R between variables p may be illustrated as follows:

$$R = A_{pxq}A_{pxq}^T + B_{pxq}^2 \tag{3}$$

This equation is a basic equation of the factor analysis.
Value $h_i^2 = \Sigma_{j=1}^q a_{ij}^2$ referred to as communality of feature X_i made precise with factors Z_j.
Value $b_i^2 = 1 - h_i^2$ (*h* is determination factor for tree branches and *b* is model tolerance factor), equal to specific factor U_j, is a specific variance. The entire resources $h_i^2 = \Sigma_{i=1}^q a_{ii}^2$ secure total determination of changeability of all X_i, through factor Z_j, As the sum of variances of variables X_i equals p, the coefficient is constituted by a group determination coefficient.

$$R_{X-Z}^2 = \frac{1}{p}\sum_{i=1}^{p} h_i^2 = \frac{1}{p}\sum_{i=1}^{p}\sum_{j=1}^{q} a_{ij}^2 \tag{4}$$

The sum of squares may be divided into parts and assigned to remaining factors Z_j, i.e.

$$\lambda_j = \sum_{i=1}^{p} a_{ij}^2 (j = 1,2,\dots,q) \tag{5}$$

This value defines the weight of jth common factor in determining changeability of set $\{X_i\}$.
Let R denote a correlation matrix of variables $\{X_i\}$. Defining the matrix of loadings with A of parts a_{ij} and rows p and columns q we may write the correlation matrix:

$$R = A \cdot A^T + B^2 \tag{6}$$

where:

$$B^2 = diag\left(b_1^2, b_2^2, \dots, b_p^2\right)$$

If matrix D is an orthogonal matrix, the transformation of factors Z^T=ZD does not change the structure of correlation matrix R due to the fact:

$$(\mathrm{A} \cdot \mathrm{D})(\mathrm{A} \cdot \mathrm{D})^{\mathrm{T}} \cdot \mathrm{A}^{\mathrm{T}} = \mathrm{A} \cdot \mathrm{A}^{\mathrm{T}} \tag{7}$$

The transformation of matrix D corresponds with the rotation of main directions denoting principal components. It is possible to make a rotation so that loadings polarize to obtain a simpler interpretation.
There is a condition that a variant of loadings' squares is maximum:

$$vara = \sum_{j=1}^{q}\left[\frac{1}{p}\sum_{i=1}^{p}\left(a_{ij}^2 - a_j^{-2}\right)^2\right] = max! \tag{8}$$

where: leads to *varimax* method expressed by Kaisera (1958) and to a maximum differentiation of loadings at the factor.
V*arimax* method focuses on the simple interpretation of columns of the factors matrix whereas the method focusing on simple explanation of matrix rows is called *quartimax method.* [1]

1 *Eksploracyjna analiza czynnikowa w badaniach struktur zespołu zmiennych obserwowanych,* Zbigniew Laudański, Biuletyn instytutu Hodowli i Aklimatyzacji roślin, Warsaw 2012,p. 77-79

On the above basis we may calculate a-posteriori probability of a break-down risk of the telematics system for a particular group of factors using the formula:

$$\sum_{j=1}^{q} a_{ij} Z_{ij} + b_i U_i$$

$$P(\mathrm{Xi}|A) = \frac{P(\sum_{j=1}^{q} a_{ij} Z_{ij} + b_i U_i) \cdot P(\frac{1}{p} \sum_{i=1}^{p} \sum_{j=1}^{q} a_{ij}^2 | \sum_{j=1}^{q} a_{ij} Z_{ij} + b_i U_i)}{P(\frac{1}{p} \sum_{i=1}^{p} \sum_{j=1}^{q} a_{ij}^2)} \quad (9)$$

CONCLUSION

Building probabilistic methods of calculating the risk of transport planning is based on a reliable analysis of all possible transport variables of a particular decision problem. A factor analysis is to group factors of the highest risk of faulty classifications of the transport system occurring under similar conditions. Thanks to such an approach it is possible to calculate a-posteriori probability of reliability of the transport system due to variables and groups of risk variables. We should remember that in the event of high differentiation of variables accounted for in the transport process where the relation of the mean to a standard deviation is greater than 20% , it may generate greater mistakes in risk calculation. It is subject to a huge variability of features. If we deal with a set of imprecise or incomplete features, we should a fuzzy set model instead of a probabilistic model.

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MODEL PROBABILISTYCZNY WYZNACZANIA RYZYKA PLANOWANIA TRASY PRZEJAZDU W SYSTEMACH TELEMATYCZNYCH

STRESZCZENIE

Praca ma na celu przybliżyć pojęcia z zakresu metod probabilistycznych w zadaniu planowania trasy przejazdu w systemach telematycznych. W zadaniu klasyfikacji zastosowano model bazujący na probabilistycznym klasyfikatorze Bayesa i funkcji gęstości prawdopodobieństwa. W części pierwszej pracy zostały opisane problemy planowania tras przejazdów we współczesnych systemach telematycznych. Część druga zawiera teoretyczne podstawy klasyfikatorów bazujących na twardych metodach matematycznych. Aby taki model miał jakikolwiek sens, należy uwzględnić pomniejsze rodzaje ryzyka związane z procesem transportu. Artykuł prezentuje metodę doboru najbardziej optymalnych parametrów do zadania planowania transportu. Tutaj niewątpliwie zwraca się uwagę na metodę redukcji zmiennych niezbędnych do planowania z zastosowaniem metody analizy czynnikowej składowych głównych z metodą rotacji czynników Varimax znormalizowaną metodą Kaisera dla cech ilościowych. Rozdział trzeci poświęcony jest procesowi planowania tras przejazdu i ryzyku jakie jest z tym planowaniem związane.

SŁOWA KLUCZOWE

planowanie transportu, analizowanie czynników, planowanie ryzyka