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TRANSPORT SYSTEM EQUILIBRIUM

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1. Introduction

Equilibrium in transport system is problem integrating itself some important aspects. Economical aspect by setting of transport system equilibrium is one of key parts of investigated problem. It means especially investigation of mutually related influence of macroeconomical and transport system each other. Other sight on equilibrium solves marketing problem of interaction of market cathegories in transport, thus transport demand and supply. Of course, technical and traffic provision face of transport system for its efficiency has the same importance. It is necessary of course for its perfect function to hold also relevant and adequate capability of transport infrastructure. This side of problem comprises thus spatial aspect, and that is why it is important to consider also possibilities of solution of interregional transportations equilibrium and next problem solution in context of transport network equilibrium. Modelling of these partial problems is naturally based on relevant factors, which influence directly and importantly particular areas of equilibrium and consequently it is possible to reflect them by means of mathematical expression.

2. General Aspects of Transport System Equilibrium

Macroeconomical aspect of transport system equilibrium works on basic macroeconomical quantities. It is related especially with basic macroeconomical aims as high level of product and its growth, high rate of employment and low rate of unemployment, stable or slightly increasing price level and keen foreign trade balance. For reaching of these aims for economy, there exist some macroeconomical tools, which are available for it. We can speak about tools related to monetary and fiscal policy, wage policy, price policy and foreign policy.

For closer examination and verification of dependences between economical and transport system mentioned in models, it is necessary to concretize components of these systems with their number expression within quantification.

One of basic indicators for assessment of economy is gross national product. It is used for assessment of economy development in country and also for comparison of economical levels of various countries each other. This macroeconomical indicator gives value of all goods and services produced in certain country in one year and that is why it is connected with transport system, because transport is very important for production development and business, because it is carrier of physical flow of material and goods. It is evident from above-mentioned facts, that relation of transport and gross domestic product is interdependent, thus transport influences creation of GDP and also transport is influenced by GDP level.

Relation between economical growth and freight transport is not proportional and according to some sources is up to double. At first economical growth influences transport demand. It is evident, that on the contrary changes in transport situation has impact on economical growth. From that reason, transport sector was and still is used as mean for reaching some aim or destination (it means for realization of regional, social and other aims). On the other side, it is often spoken, that future growth of flows of foreign goods, which arises among others also from further integration of national economics, can have negative impact on economical growth potential from reason of unsufficient available infrastructure. Consider to the fact that freight transport demand is strictly derived demand, it is necessary to learn very exact reflection of economical activities impact. Complexity of goods demand modelling follows from active interaction between transport system and other areas of economy. Principle of derived demand assumes, that transportation of goods is completely dependent on spatially separated production and consumer activities. In addition transport policy generates dynamic and social impacts on remaining part of economy including distribution of incomes, business, investment policy etc.

If we differ among types of models, literature differs between modelling of aggregate freight demand and desaggregated approaches. Aggregated models deal with flows of goods among the sectors of industry or geographical regions. Desaggregated models are focused on flows of goods united with particular enterprises.

The most of freight demand models is still of desaggregated type, corresponding to classical Four Step Model. Transport problem in desaggregated approach is considered from the basis of separate deliveries, which requires individual customers to make amount of decisions connected with transportation. Each decision is considered as choice from isolated set of alternatives. Process of choice is influenced besides by characteristics of transport services, goods, which is necessary to haul, market and characteristics of firms requiring transport. Unfortunately applicability of this approach was heretofore constrained not only by enorm amount of data acquired for effective estimation of this model.

Modelling of freight transport traditionally uses simple multiple relation Cobb Douglas model, in which coefficients express elasticities:

$$y = kx_1^{\alpha} x_2^{\beta} x_3^{\chi} \ldots$$

where α is elasticity y considering to variable x_1 and expresses proportional rate of change y for proportional change of x_1 and coefficients β and γ could be expressed analogically.

Usual specification of this model is expressed both within total transportation or transport by each transport mode in tonokilometres. Explaining variables express e.g. economical activities, GDP or industrial production, rather rarely prices of various transport modes are mentioned.

It showed, that passenger transport has inclination rather to higher elasticity with respect to economical activities growth and lower own price elasticity than freight transport. It is evident, that significant differents between short-term and long-term price elasticities exist, which are typically higher by long-term than by short-term elasticity. Presented elasticities are usually derived from correlations between aggregated data time series or cross sections of aggregated series within whole countries or regions. Elasticities can be calculated from transportation models, which estimate transport on each edge of geographical network by only one changing parametre e.g. price of one transport mode (proportionally changed for each network edge) or fuel price. Derived elasticities are sure highly dependent on local conditions of competion among transport modes and values which can be derived for particular network, can differ from values on one or other network and depend on various conditions on soever network on average.

All values usually reflect past relations. Possibilities of changes in course of time were studied qualitatively by consultations with experts as by values for hauled goods. Uncertainty of judged factors appeared as the most important by acceptance of transport policy decisions, changing demographical factors, concentration of population, reorganisation of work time, internalisation, development of tourism, possible changes in process of European integration with increasing emphasis on national interests, increasing sensitivity to environment and heightened press to public funds. All mentioned factors could move to various directions.

Complex multiregional economically-transport approach generally requires following basic elements:

- compliance of import and export between regions,
- comprising of mobile and immobile sources and means,

- transport costs.

Used region comprises relation between regions, because behaviour of independent regions is not researched as in case of budget determination or decentralization problems. That is why character of mutually regions influence is starting point of multiregional approach to transport.

Other models in regional economics are Input-Output models, which have a long tradition. These IO models are mostly used for studies that wish to incorporate structural economic relationships, e.g. interindustry linkages by way of intermediate deliveries of goods and services. By calculating direct and indirect effects of exogenous variables expenditures, one may obtain multipliers and effects on employment and use of resources. Transport and IO models have usually been approached from interregional trade perspective (economic-base). Here interregional gravity models are sometimes combined with the intersectoral IO models to arrive completely variable interregional or intersectoral models. More limited is the approach to use fixed input-output coefficients, which can be regarded as the straightforward extension of general IO models. Here one may repeat a given sectoral disaggregation for each region. The fixed interregional trade coefficients are to be interpreted as constant patterns of supply areas or channel. This is an important assumption, which holds more strongly for commodities which are associated with significant transportation costs (bricks, cement, glass etc.) than for those with negligible transportation costs. Another class of models is formed by multicountry models using trade-theoretic concepts.

Economical basis of equilibrium models is market, where demand and supply mutually influence on basis of price signals. It is assumed that markets are transparent. Besides these factors (raw materials and final goods), transport services markets are considered. In case of freight transport, it means that it presumes spatially separated markets for particular kinds of goods. Focusing on spatial aspect of equilibrium, it is possible to speak about following models.

When space is considered from a discrete, multiregional perspective and when transport costs are fixed and demand and supply functions for a single product are given, then we have spatial price equilibrium, characterized by non-negative, homogenous and unique market demand and supply prices, then we assume no excess demand or supply in all regions, and on each interregional route the delivered price in the importing region must at least equal the producer price in the exporting region plus transportation costs, when this is not the case, there is no positive interregional transportation or trade flow.

General formulation of multiregional model of spatial price equilibrium for one product is:

$$minimize \sum_{o} \int_{0}^{x_o} S_o(z)dz - \sum_{d} \int_{0}^{y_d} D_d(z)dz + CN$$

where:

S_o .... the inverse supply functions,
D_d .... the inverse demand functions,
CN .... the total transportation costs.

The latter is a function of all link-specific haulage (t_o^d stands for the haulage of goods from source *o* to destination *d*). These haulage have to satisfy non-negativity restrictions. Supplies X_o at origins *o* are equal to the sum of all haulages out of *o*:

$$X_o = \sum_d t_o^d$$

and demands Y_d at destinations *d* are equal to the sum of all haulages arriving in region *d*:

$$Y_d = \sum_o t_o^d$$

Cost function *CN* belonging to an interregional link is associated with a single unique transportation firm, implying as many firms as links. With one additional assumptions, namely that n_o^d are fixed costs per unit of the good to traverse link *o*-*d*, one obtains the most common cost structure used:

$$CN = \sum_o \sum_d n_o^d * t_o^d$$

Interregional transportations have to realize on transport networks. Traffic volume and capacity of transport means are necessary to reflect them also to transport network. Models of transport network have completely microeconomical and detailed orientation and are usable above all by single goods analysis. Usually they can deal more strictly with freight transport, which need real transport infrastructure comprising network complex with e.g. freight terminals. Usually they are connected in terms above all with multimodal and multiproductional problems.

Between demand volume for intereregional haulages V_{ij} for each pair of origin and destination *i* a *j* and quality of provided transport services in concrete haulages S_{ij} , there exists dependence expressed by transport resistance. In other words, traffic volume of goods from *i* to *j* is the function of provided transport services quality:

$$V_{ij} = D\ (S_{ij}) \quad \text{for each } ij.$$

This relation can be naturally transfered to each segment of transport market expressed by kind of hauled loads, beacuse their haulage demand is also various.

Equilibrium on given route can be expressed as equity of:

$$\sum_q V_{ijl}^q = V_{cl}$$

where:

V_{cl} .... transportation capacity of route *l*.

The level of quality services S_{ij} on given route is depend on level of services on particular edges creating the whole route. If between given nodes *i* and *j* exists *n* routes, then it is possible to consider transportations between particular routes also as functions of level of provided services on each one. Traffic volume on given edge is sum of traffic volume on all routes, which comprise this edge as their component. Analogically it is possible to divide certain route to set of partial routes. Then traffic volume on given partial route equals sum of traffic volume on all routes, which comprise this route as their component:

$$V_{ij} = \sum_{n} V_{ij}^{\ n}$$

Considering of network characteristics of combined transport-haulage models, it is usual to use consumer-mentioned network, which was created by certain edges (re-load, interlinked and other key edges) with more detailed networks specified by carriers. In relation to hauliers, carriers and networks, it is necessary to note two Wardrop principles, which determine conditions for user optimum, resp. optimum of network flows system. Optimal user equilibrium is reached, when no user has motivation to reduce his transport costs by one-side action. Optimal system equilibrium is reached, when marginal total costs of transport alternatives equals. Haulier can be modelled by the first Wardrop principle, which is interpreted as minimization of delivered goods prices. Equilibrium conditions appears in case that all used routes between origin and destination of haulage have equal minimal costs, while all unused routes have higher or equal costs. The second Wardrop principle of optimization system using model programming formulations models all transport costs of all routes as minimal.

For transport network equilibrium, it is very important to know degree of its utilization. One of tools which can lead to more effective utilization of existing communication, is route price. This price should be variable in dependence on congestion level. Theory of informational effects in transport in essence works on user travel costs, when besides money time value it is considered also uncertainty value in travel behaviour of network user, which is dependent on level of user information. Travel costs of transport users can be expressed from economical viewpoint by following general cost function:

E (travel costs) = α E(travel time) + β S_d *(travel time)*

where:

S_d .... error of stochastical variable *travel time,*
E .... assumed mid value of given variable,
α, β .... money time value and uncertainty (risk) value.

This model of general cost function was frequently used in the past. For calculation of presumed travel cost, travel time is important, but non-less important role is assigned also to uncertainty in travel behaviour, which is expressed in this function as $\beta\ S_d$ (*travel time*).

User travel costs are variable also in dependence on uncertainty considering transport situation on given infrastructure network. There exist 4 types of equilibrium models of stochastical network with information and with uncertainty costs, where in each of them travellers made an effort to find optimal travel costs:

- N – no information is available to users and travellers decide only on the basis of assumed travel costs,
- I – works on assumption, that information of actual transport costs is available to all users, and it means that travellers decide rather on the basis of real costs than presumed costs,
- P – information devoted to part of road users are available from outside,
- E – inner-formed inside model – choice of travellers to have information depends on their personal private utilities and costs joined with information.

All these models works on binomical Bernoulli probability distribution with probabilities of various states of travel time in dependence on various height of capacity of transport network.

Basic model N reflects the situation, when no information is available. Equilibrium of this model is described by following equation:

$$\alpha\cdot\left(\left(1-p\right)\cdot C^0\left(N_N\right)-p\cdot C^1\left(N_N\right)\right)+\beta\cdot\sqrt{p\cdot\left(1-p\right)}\cdot\left(C^1\left(N_N\right)-C^0\left(N_N\right)\right)=D\left(N_N\right)$$

Left side of equation expresses assumed travel costs and right side willingness to pay for transport network usage. For marginal network user N_N ,assumed personal costs equal personal utility. This user is indifferent to using network or no.

Given equilibrium equation works on Bernoulli distribution, where with probability (1-p) will be travel time $C^0(N)$, with probability p will be $C^1(N)$. State 0 means high capacity on transport network, state 1 low capacity (caused by e.g. travel accident, work on road etc.).

3. Equilibrium Modelling of Macroeconomical and Transport System

Sense of mentioned modelling is verification of hypothesis, which speak about mutual influence of transportation and macroeconomical system in various time horizons. Verification of this hypothesis is based on mathematical modelling by usage of statistical methods working with selected key indicators of both systems.

In compliance with dynamical access to modelling, time series of selected indicators are used in quartal data for higher relevant value of model. Own selection of indicators was put on transport volume of particular transport modes of passenger and freight transport in natural units (tonokilometres and personkilometres) for transport system and real gross domestic product in fixed prices of 2000 year for macroeconomical system as the most representative variables.

As the first step of quartal data procession of these variables, it was necessary to shift to examination, if individual time series of quartal data contains seasonal factor themselves. This verification was apllied on all time series of transport volume in particular transport modes. For testing of relevant inclusion of seasonal parametre in model, hypothesis test of seasonality existence was used. It verifies zero hypothesis, if seasonal amplitudes for all seasons equal zero against alternative hypothesis, that at least for some season this seasonal amplitude does not equal zero. Test criterium is F-statistics in form:

$$F = \frac{m\sum_{j=1}^{r}\left(\bar{y}_{.j} - \bar{y}\right)^2}{\left(r-1\right)\sigma^2}$$

where:

i = 1….m .... number of years,

j = 1….r .... number of partial periods within year (r = 4),

and

$$\sigma^2 = \frac{\sum_{i=1}^{m}\sum_{j=1}^{r}\left(y_{ij} - \bar{y}\right)^2 - r\sum_{i=1}^{m}\left(\bar{y}_{i.} - \bar{y}\right)^2 - m\sum_{j=1}^{r}\left(\bar{y}_{.j} - \bar{y}\right)^2}{\left(r-1\right)\left(m-1\right)}$$

If time serie does not contain important seasonal factor, there is used Brown simple exponencial smoothing for calculation of smoothed values $\hat{y}_t$ in form:

$$\hat{y}_t = \left(1-\alpha\right)\cdot y_t + \alpha\cdot\hat{y}_{t-1}$$

where:

α .... smoothing constant.

Modelling of trend of time serie by this method is dependent to setting of smoothing constant optimal value, which assures that gained sequence of residua really represents stochastic component. As criterium was chosen Durbin-Watson test, which use test criterium of statistics with residua sequence of stochastical component estimations ε in form:

$$DW = \frac{\sum_{t=2}^{n}\left(\hat{\varepsilon}_t - \hat{\varepsilon}_{t-1}\right)^2}{\sum_{t=1}^{n}\hat{\varepsilon}_t^{\,2}}$$

Time series of hauling performances of transport modes including important seasonal component with time serie of quarterly data of seasonaly unadjusted real gross domestic product were smoothed by Holt-Winters method of exponencial smoothing with three smoothing constants: α for trend component, β for trend increment and γ for seasonal component within additive decomposition of time series. Smoothed values $\hat{y}_t$ of additive Holt-Winters method are set by following relations:

$$\hat{y}_t = \hat{a}_{0,t} + \hat{s}_t ,$$

where following particular estimation components express:

$\hat{a}_{0,t} = \alpha \cdot (y_t - \hat{s}_{t-s}) + (1-\alpha) \cdot (\hat{a}_{0,t-1} + \hat{b}_{1,t-1})$ .... linear trend,

$\hat{b}_{1,t} = \beta \cdot (\hat{a}_{0,t} - \hat{a}_{0,t-1}) + (1-\beta) \cdot \hat{b}_{1,t-1}$ .... trend increment,

$\hat{s}_t = \gamma \cdot (y_t - \hat{a}_{0,t}) + (1-\gamma) \cdot \hat{s}_{t-s}$ .... seasonal variation,

s .... number of seasons per year.

After modelling and testing of stochastical components estimations, we can process the correlations of this components to learn closeness of relations between indicators of hauling performance and gross domestic product. We use correlation coefficient in form:

$$r_{X,Y} = \frac{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x}) \cdot (y_i - \bar{y})}{\sqrt{\frac{1}{n} \cdot \sum_{i=1}^{n}(x_i - \bar{x})^2} \cdot \sqrt{\frac{1}{n} \cdot \sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

where always one variable (e.g. y) represents residues – stochastical components of GDP and the second variable x residues of certain hauling performance. Relations of these quantities are measured within the same time period. Next there were examined also delayed correlations of residual components of quantities mutually with shift of 1 up to 8 periods – quarters, thus starting with correlation of data mutually delayed for one quarter and finishing with data correlation two-years delayed. Correlation of residues is examined in the sense of reciprocal dependences, thus:

- delay of GDP change on dependence on hauling performance,
- delay of hauling performance change on dependence on GDP.

More close relations between correlated variables are modelled by regression analysis method. General form of linear model is:

$$Y_i = \alpha + \beta \cdot X_i + \varepsilon_i$$

where point estimations a and b of parametres α and β are calculated by the least squares method.

$$b = \frac{n\sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i}{n\sum_{i=1}^{n} x_i^2 - \left(\sum_{i=1}^{n} x_i\right)^2} \qquad a = \frac{\sum_{i=1}^{n} y_i - b\sum_{i=1}^{n} x_i}{n}$$

Validity of model is verified by testing methods of hypothesis for choice of regression function, thus individual t-tests of zero values of particular regression parametres and total F-test. Next the model is proved by determination index, which sets part of time series values variations of dependent variable explained by constructed regression model.

4. Results of Modelling

Results of correlation coefficients show generally unclose dependence between residual components, in majority of cases independence, and that is why it is not possible to confirm strictly real causal connection between variables themselves and these relations are not appropriate for mathematical modelling. The highest values of correlation coefficients from analysis close from left to at least 0,7; which could create basis for next modelling in limited rate, belong in certain cases only to relation of hauling performance of road freight transport and GDP in the same time period, next to dependence of hauling performance on GDP in successive half-year intervals, when in addition direct proportion changes to indirect proportion and vice versa. This fact is reflected by sign alternation of correlation coefficient. These relations were modelled by method of one-dimensional linear regression, because with examination of relations within each next delay extent of each time series, which creates element of modelling, changes.

Results of modelling by one-dimensional linear regression of mutual influence of road freight transport with various time delay for certain number of quarters according to important values of correlation coefficients are in following table:

Fig. 1 *Equilibrium Models*

DELAY	MODEL
0	GDP=193632,35+39,05 HP
0	HP=2922,18+0,013 GDP
2	HP=4547,58-0,010 GDP
4	HP=3452,58+0,012 GDP
6	HP=4661,06-0,011 GDP
8	HP=4289,77+0,012 GDP

Source: authors

According to results of individual t-tests and F-tests, these regression functions are usable, because they confirmed alternative hypothesis of existence of non-zero regression parametres. Unfavourable results for applicability of functions has determination index, which does not confirm by any of model functions sufficient percentage of explained variability of dependent variable.

Modelling of mutual dependences representing quantities of both systems with usage of delayed correlations confirmed some marks of certain rate of dependence, howbeit statistically unimportant by chosen 95% level of statistical significance. It concerns dependences of variable GDP in actual quarterly period on hauling performance of some previous quarterly period only in some cases, namely in freight road transport (half-year and one-year delay in sequence of indirect and direct dependence) and freight air transport (quarterly delay with direct dependence, delay of 3 quarters with indirect dependence and 5 quarters with direct dependence). This unclose dependence appears also by individual automobile transport with one-year and two-year delay in indirect proportion.

On the contrary, surprisingly inversely delayed dependences, thus dependence of transport system indicators in actual period on economical indicator of previous periods, appear more frequently in acquired correlation results. It is necessary to remind mentioned marked unclose dependence. Concretely we can speak about relation of air passenger transport and GDP (one-quarter delay in direct proportion, then 3; 5 and 7 quarters delay with alternating proportion and two-year delay with indirect proportion) and air freight transport and GDP (delay of 3 quarters with direct proportion). The most noticable impacts of changes in GDP appears in road freight transport with half-year, one-year, one-and-half year and two-year delay and with alternating dependence starting with indirect proportion.

5. Conclusion

Described and selected methodology for application of chosen structure and kind of enter data of selected key representative quantities did not prove in general expression close relations between macroeconomical and transport system, howbeit neither by examination of relations between these quantities with mutual delay of various number of partial time periods. Selection of representative quantities of both systems used in this work does not have to be far only one possible alternative, relations of various economical and transport variables can be modelled, which could closely and in detail specify concrete partial relation problems between systems. Nevertheless, author made an effort to select as possible quantities with high rate of aggregation also with simultaneous possibility of reflection of specific transport subsystems and their contributions to economical system development.

From viewpoint of existing approaches and opinions on interaction of transport and economical system, results of this work by modelling of dependences on the basis of selected key variables and chosen methodology does not confirm generally respected and accepted facts, some of these results evidently are rather inclined to their destruction.

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Resumé

ROVNOVÁHA V DOPRAVNÍM SYSTÉMU

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Rovnováha v dopravním systému je problematikou integrující v sobě několik důležitých hledisek. Ekonomické hledisko při stanovení rovnováhy v dopravním systému je jednou z klíčových součástí zkoumaného problému. Jedná se zejména o vzájemné působení makroekonomického a dopravního systému. Jiný pohled na rovnováhu řeší marketingový problém interakce tržních kategorií v dopravě, tedy dopravní poptávky a nabídky. Samozřejmě neméně důležitá pro efektivnost dopravního systému je i technická a provozní stránka systému, k jehož fungování je třeba samozřejmě i náležitá kapacita dopravní infrastruktury. Tato strana mince zahrnuje právě hledisko prostorové, tedy je třeba i brát v úvahu možnosti řešení rovnováhy meziregionálních přeprav, a dále řešení problému ve smyslu rovnováhy na dopravní síti. Modelování těchto dílčích problémů přirozeně vychází z relevantních faktorů, které jednotlivé oblasti rovnováhy přímo a významně ovlivňují a zároveň je možno je podchytit prostřednictvím matematického vyjádření.

Těžištěm tohoto příspěvku je právě řešení, odhalení a porozumění problému vztahů makroekonomického a dopravního systému. Základ analýzy tvoří vhodně vytipované reprezentativní veličiny obou systémů a volba struktury a druhu vstupních dat, které tvoří čtvrtletní údaje reálného hrubého domácího produktu ve stálých cenách roku 2000 a přepravních výkonů osobní a nákladní dopravy jednotlivých dopravních oborů. Identifikaci vzájemného vztahu mezi zvolenými proměnnými makroekonomického a dopravního systému poskytuje korelační analýza náhodných složek, které předchází adekvátní vyrovnání a očištění dat s ověřením platnosti získaných výsledků použité techniky vyrovnání. V případech, kde prokáže korelační analýza těsné závislosti, je provedeno regresní modelování z hlediska vzájemného rovnovážného stavu obou systémů. Pro úplnost analýzy se uvažuje rovněž fakt, že stav proměnné jednoho systému se může

projevit ve druhém systému s jistým zpožděním, proto je pozornost věnována i opožděným korelacím navzájem inverzních závislostí s různým časovým posunem. Platnost výsledků regresního modelování včetně modelů vycházejících z opožděných korelací je ověřována testovacími metodami pro zkoumání regresních parametrů a míru vysvětlení skutečnosti modelem.

Summary

TRANSPORT SYSTEM EQUILIBRIUM

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Equilibrium in transport system is problem integrating itself some important aspects. Economical aspect by setting of transport system equilibrium is one of key parts of investigated problem. It means especially investigation of mutually related influence of macroeconomical and transport system each other. Other sight on equilibrium solves marketing problem of interaction of market cathegories in transport, thus transport demand and supply. Of course, technical and traffic provision face of transport system for its efficiency has the same importance. It is necessary of course for its perfect function to hold also relevant and adequate capability of transport infrastructure. This side of problem comprises thus spatial aspect, and that is why it is important to consider also possibilities of solution of interregional transportations equilibrium and next problem solution in context of transport network equilibrium. Modelling of these partial problems is naturally based on relevant factors, which influence directly and importantly particular areas of equilibrium and consequently it is possible to reflect them by means of mathematical expression.

Problems of transport system equilibrium cannot be solved strictly in complex form, because there exist some various aspects of its solution. Economical viewpoint by setting of transport system equilibrium is one of parts of this problem, but important role for transport system efficiency is put also on technical and operational capaticies of this system, which requires for its function necessary of course sufficient infrastructure as well. This contribution otherwise comprises in previous text in general model form just possible solutions of system equilibrium from spatial viewpoint, thus reflects equilibrium solution of interregional or multiregional transportations, and next problem solution in sense of equilibrium on transport network. Modelling of this partial problems naturally works on relevant factors, which influence directly and significantly particular areas of equilibrium and simultaneously it is possible to express them by mathematical methods.

The main goal and focusion of this paper is identification of relation between macroeconomical and transport system on basis of appropriately selected representative variables and then mathematical modelling of them from viewpoint of their mutual equal - balance state. Mission of solution results is not only verification of assumptions of concrete interaction between both systems, but on the basis of gained results also assessment of transport mode subsystems role in sense of their contribution to macroeconomical system. By transport system equilibrium modelling in relation to macroeconomical system, concrete data are applied from those final equilibrium model of both systems is derived including verification of its validity by means of relevant mathematical methods.

Solution, detection and understanding to problem of relations between macroeconomical and transport system is created by appropriately selected representative variables of both systems and choice of structure and kind of enter data, which are quartal data of real gross domestic product in fixed prices of 2000 year and of traffic volumes in personal kilometres and tonal kilometres of passenger and freight transport for particular transport modes. Identification of mutual relation between selected variables of macroeconomical and transport system provides correlational analysis of stochastical components of time series. Before it, adequate smoothing and adjusting of data must be processed with verification of validity of gained results from used technique for smoothing. In cases, when correlation analysis confirms close dependences, regressional modelling is processed from viewpoint of mutual equilibrial state of both systems. State of variable of one system can also impact other system with certain delay, and that is why the attention is devoted also to delayed correlations of mutually inverse dependences with various time shifts. Results of regressional modelling including models followed from delayed correlations are veryfied by testing methods for examinations of regressional parametres and rate of explanation of reality by models. Mission of solution results is not only verifiation of assumptions of concrete interactions between both systems, but also assessment of role of partial transport modes to their support of economical system with additional ideas of causes.

Zusammenfassung

GLEICHGEWICHTIGKEIT IN VERKEHRSSYSTEM

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Das Gleichgewichtigkeit in Verkehrssystem ist die Problematik einige von wichtigen Sichte. Die ökonomische Sicht bei der Bestimmung der Gleichgewichtigkeit in Verkehrssystem ist Schlüsselpunkt des Problems. Es geht um die Zusammenwirkung Makroökonomisch- und Verkehrssystem. Aus Marketingproblem kann man die Gleichgewichtigkeit zwischen Verkehrsnachfrage und Verkehrsangebot lösen. Für die Verkehrseffektivität ist auch die Kapazität der Verkehrsinfrastruktur wichtig. Bei der Modellierung diesen Problemen geht es über die Lösung die Faktoren, die die Gleichgewichtigkeit direkt und indirekt beeinflussen.