VERIFICATION OF HYPOTHESIS OF TRANSPORT AND ECONOMY INTERACTION MODEL

VERIFIKACE HYPOTÉZ MODELU INTERAKCÍ DOPRAVY A EKONOMIKY

Daniel Salava[1], Libor Švadlenka[2]

Summary: The aim of this contribution is verification of hypothesis, which speaks about mutual influence of transport and economical system in various time horizons. The research basis with partial hypothesis is interactive relation model of transport and economical system. Verification of this hypothesis is based on mathematical modelling by usage of statistical methods working with selected key indicators of both systems.

Key words: transport system, economical system, gross domestic product, correlation, exponencial smoothing, seasonal factor

Anotace: Cílem tohoto příspěvku je ověření hypotéz, jež hovoří o vzájemném působení dopravního a ekonomického systému v různých časových horizontech. Výchozí základnu s dílčími hypotézami tvoří interakční model vazeb dopravního a ekonomického systému. Ověření těchto hypotéz je postaveno na matematickém modelování za použití statistických metod prostřednictvím vybraných klíčových ukazatelů obou systémů.

Klíčová slova: dopravní systém, ekonomický systém, hrubý domácí produkt, korelace, exponenciální vyrovnávání, sezónní faktor

1. INTRODUCTION

Modelling of interaction of transport and economical systems is based on relation model, which reflects some hypothethical dependences based on logical judgement following from practical function of both systems. Prime facts of this interaction model the most important for our analysis can be expressed by four partial hypothesis as under-mentioned.

In compliance with dynamical access to modelling, time series of selected indicators are used in quarterly 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 personal kilometres) for transport system and real gross domestic product in fixed prices of 2000 year for macroeconomical system as the most representative variables.

[1] Ing. Daniel Salava, Ph.D., University of Pardubice, Jan Perner Transport Faculty, Department of Transport Management, Marketing and Logistics, Studentská 95, 532 10 Pardubice, Tel.: +420 466 036 376, E-mail: daniel.salava@upce.cz

[2] doc. Ing. Libor Švadlenka, Ph.D., University of Pardubice, Jan Perner Transport Faculty, Department of Transport Management, Marketing and Logistics, Studentská 95, 532 10 Pardubice, Tel.: +420 466 036 375, E-mail: libor.svadlenka@upce.cz

Tab. 1 – Partial hypothesis of interaction model

SYSTEM IN PERIOD T_0/T_1	**SYSTEM IN PERIOD T_1**	$X_{T1} = f(X_{T0})$
TRANSPORT T_0	ECONOMICAL	YES
TRANSPORT T_1	ECONOMICAL	NO
ECONOMICAL T_0	TRANSPORT	NO
ECONOMICAL T_1	TRANSPORT	YES

Source: Autors on basis of [2]

2. IDENTIFICATION OF SEASONAL FACTOR IN TIME SERIES

As the first step of quarterly data procession of these variables, it was necessary to shift to examination, if individual time series of quarterly data contain 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 parameter in model, hypothesis test of seasonality existence was used. It verifies null 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:

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

where:

i = 1….m number of years,

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

and

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

This F-statistics has F-distribution with *(r-1)* and *(r-1)(m-1)* degrees of freedom by validity of null hypothesis. The results of this test apllied on partial indicators of hauling performance by level of significance $\alpha = 0{,}05$ are included in following table.

Tab. 2 – Results of seasonal factor testing

TRANSPORT MODE	RESULT OF *F*-TEST	VALIDITY OF H_0	SEASONALITY
RAIL PASSENGER	12,268	REFUSED	YES
BUS PUBLIC	2,490	UNREFUSED	NO
URBAN PUBLIC	0,704	UNREFUSED	NO
AIR PASSENGER	93,185	REFUSED	YES
RAIL FREIGHT	6,063	REFUSED	YES
ROAD FREIGHT	8,218	REFUSED	YES
WATER FREIGHT	2,244	UNREFUSED	NO
AIR FREIGHT	9,212	REFUSED	YES
PIPELINE	4,940	REFUSED	YES

Source: Authors

It is evident, that important share of seasonal factor was confirmed by majority of indicators.

3. TIME SERIES SMOOTHING

We assumed aditive decomposition of these time series in the form:

$$y_t = T_t + S_t + C_t + \varepsilon_t \quad (3)$$

It is very important to separate random component, which will be used to correlation analysis. If time series do not contain important seasonal factor, this residual component would be separated by Brown simple exponencial smoothing, where smoothed values $\hat{y}_t$ in the form:

$$\hat{y}_t = (1-\alpha)\cdot y_t + \alpha \cdot \hat{y}_{t-1} \quad (4)$$

where α is smoothing constant.

These smoothed values determinate only trend component of time series, thus next component is just required random - residual component, which can be reached by real value minus smoothed value. Other important task is 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 uses test criterium of statistics with residua sequence of stochastical component estimations ε in form:

$$DW = \frac{\sum_{t=2}^{n}(\varepsilon_t - \varepsilon_{t-1})^2}{\sum_{t=1}^{n}\varepsilon_t^{\,2}} \quad (5)$$

Brown simple exponencial smoothing was used by bus publis transport, urban public transport and water freight transport, where has not been confirmed significant seasonal factor. Results of this smoothing are included in following table:

Tab. 3 – Results of Brown smoothing

TRANSPORT	SMOOTHING CONSTANT	DW-TEST VALUE
BUS PUBLIC	0,774	1,99928169
URBAN PUBLIC	0,465	2,00275179
WATER FREIGHT	0,455	2,00027273

Source: Authors

Time series of other transport mode hauling performance with significant seasonal component (also with 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 in aditive form in compliance with used methodology within aditive decomposition of time series. Smoothed values $\hat{y}_t$ of aditive Holt-Winters method are determined by following relations:

$$\hat{y}_t = \hat{a}_{0,t} + \hat{s}_t \text{ , where} \quad (6)$$

$$\hat{a}_{0,t} = \alpha \cdot (y_t - \hat{s}_{t-s}) + (1-\alpha) \cdot (\hat{a}_{0,t-1} + \hat{b}_{1,t-1}) \text{ is estimation of linear trend component,} \quad (7)$$

$$\hat{b}_{1,t} = \beta \cdot (\hat{a}_{0,t} - \hat{a}_{0,t-1}) + (1-\beta) \cdot \hat{b}_{1,t-1} \text{ is estimation of trend increment,} \quad (8)$$

$$\hat{s}_t = \gamma \cdot (y_t - \hat{a}_{0,t}) + (1-\gamma) \cdot \hat{s}_{t-s} \text{ is estimation of seasonal fluctuations,} \quad (9)$$

index s determinates number of seasons per year.

Results are included in following table:

Tab. 4 – Results of Holt-Winters smoothing

TRANSPORT MODE	SMOOTHING CONSTANT			DW-TEST VALUE
	α	**β**	**γ**	
RAIL PASSENGER	0,66	0,66	0,32	2,000763787
AIR PASSENGER	0,86	0,84	0,15	2,001258637
RAIL FREIGHT	0,56	0,26	0,40	2,001588201
ROAD FREIGHT	0,75	0,77	0,15	2,000364082
AIR FREIGHT	0,77	0,30	0,41	2,000981455
PIPELINE	0,47	0,71	0,28	1,999888705
GDP	0,90	0,78	0,20	2,000535236

Source: Authors

4. RELATIONS CLOSENESS OF TRANSPORT AND ECONOMICAL SYSTEMS

After modelling and testing of random components estimations, these will be analysed by correlation for identification of relations closeness between indicators of hauling performance and gross domestic product. It is determinated by correlation coefficient in the form:

$$r_{X,Y} = \frac{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})\cdot(y_i - \bar{y})}{\sqrt{\frac{1}{n}\cdot\sum_{i=1}^{n}(x_i - \bar{x})^2}\cdot\sqrt{\frac{1}{n}\cdot\sum_{i=1}^{n}(y_i - \bar{y})^2}} \quad (10)$$

where always one of variables (e.g. y) represents residua – random components of GDP and other variable x residua of hauling performance of certain transport mode. These correlations determinate relations between both systems represented by these quantities in the same time horizont - period.

Tab. 5 – Correlation between GDP and hauling performances

TRANSPORT MODE	CORRELATION COEFFICIENT
RAIL PASSENGER	0,378213
BUS PUBLIC	0,003345
URBAN PUBLIC	0,017387
AIR PASSENGER	-0,00128
RAIL FREIGHT	0,161799
ROAD FREIGHT	**0,670278**
WATER FREIGHT	0,393266615
AIR FREIGHT	0,213198
PIPELINE	0,220499

Source: Authors

The results of these one-dimensional correlations, where correlation coefficient determinates relations closeness always between random components of GDP and hauling performance of particular transport modes, are included in under-mentioned table and show practically only one closer relation between GDP and hauling performances of road freight transport residua. Value of this coefficient is 0,67 – the nearest to figure 1. It could be theoretically mentioned to next modelling, other coefficients reflect very open or zero connection of correlated quantities. But in this context it is necessary to mention, that this analysis examines quantities interaction only in the same time period, when change of one variable has not to influence immediatelly course of other variable yet. And that is why also delayed correlations of residual components of these quantities were processed with delay of one up to eight periods – quarters, thus firstly by correlation of data delayed reciprocally for one quarter and finally by correlation of data with two-years delay.

Residua correlation is examined in sense of mutual dependences:

- with which delay GDP is (or not) influenced in dependence on hauling performance,
- with which delay hauling performance is (or not) influenced in dependence on GDP.

Results of residua correlation coeficients for particular delays are included in under-mentioned tables for passenger and freight transport of individual transport modes.

Tab. 6 – Delayed correlation between GDP and passenger hauling performances

DELAY	RAIL		BUS PUBLIC		URBAN PUBLIC		AIR	
	GDP(T)	T(GDP)	GDP(T)	T(GDP)	GDP(T)	T(GDP)	GDP(T)	T(GDP)
1	-0,11133	0,084312	0,152422	-0,22183	0,134467	-0,11247	-0,3239	**0,58236**
2	-0,45776	-0,19908	0,015053	-0,04152	0,046126	0,057732	-0,14584	0,036013
3	-0,02656	-0,10021	-0,20255	0,291936	-0,15932	0,245995	0,445995	**-0,58045**
4	0,461185	0,280799	0,004029	0,045232	-0,09828	-0,05672	0,01855	-0,41875
5	0,176602	-0,05118	0,143279	-0,40434	0,058361	-0,17411	-0,28964	**0,618187**
6	-0,29011	-0,17552	0,021958	-0,00756	0,048051	0,032052	-0,19712	0,404862
7	-0,29874	-0,07859	-0,21113	0,484347	-0,05442	0,164286	0,319945	**-0,59801**
8	0,157459	0,125715	0,090305	0,011936	-0,05899	0,01893	0,153128	**-0,53092**

Source: Authors

Tab. 7 – Delayed correlation between GDP and freight hauling performances

DELAY	RAIL		ROAD		WATER		AIR	
	GDP(T)	T(GDP)	GDP(T)	T(GDP)	GDP(T)	T(GDP)	GDP(T)	T(GDP)
1	0,038398	0,389074	0,209773	-0,14321	0,029227	0,091194	**0,622943**	-0,40724
2	-0,26979	-0,10775	**-0,53711**	**-0,65881**	-0,37565	-0,36572	-0,42382	-0,30779
3	-0,08003	-0,10571	-0,31177	-0,03218	-0,06135	-0,16869	**-0,5546**	**0,529889**
4	-0,01273	0,010435	**0,506967**	**0,70408**	0,311108	0,342853	0,353537	0,256682
5	0,265935	0,167595	0,220748	0,057161	-0,00121	0,212722	**0,562115**	-0,34554
6	-0,18422	-0,07328	-0,45196	**-0,69583**	-0,26359	-0,30536	-0,35083	-0,37931
7	-0,08484	0,042532	-0,17226	-0,07303	-0,04882	-0,25169	-0,31556	0,300382
8	-0,12821	-0,043	0,442865	**0,716139**	0,256501	0,300346	0,24561	0,395228

Source: Authors

Tab. 8 – Delayed correlation between GDP and freight hauling performances - pipeline

DELAY	PIPELINE	
	GDP(T)	T(GDP)
1	-0,12334	0,373326
2	-0,42797	-0,30023
3	-0,10473	-0,31223
4	0,326174	0,241553
5	0,285597	0,404157
6	-0,26828	-0,34604
7	-0,19273	-0,26966
8	0,412566	0,275014

Source: Authors

The results in tables show in majority of cases again very open relations between residual components of quantities, and that is why it is not possible to assume real casual connection between quantities themselves and not to model them mathematically with reliable relevant conclusions as well. The highest possible coefficients from mentioned analysis approximating from left at least to value 0,7, which would create in certain limited rate the basis for next modelling, belong in some cases only to relation of hauling performance of road freight transport and GDP in the same time period, and then dependences of hauling performance on GDP in successive half-year intervals, when in addition positive dependence shifts to negative dependence and vice-versa. It is confirmed also by change of sign of correlation coefficient.

5. CONCLUSION

Mentioned analysis brought following results:

SYSTEM IN PERIOD T_0/T_1	SYSTEM IN PERIOD T_1	DEPENDENCE $X_{T1} = f(X_{T0})$
TRANSPORT T_0	ECONOMICAL	YES

This hypothesis was not confirmed in relation to any transport mode.

SYSTEM IN PERIOD T_0/T_1	SYSTEM IN PERIOD T_1	DEPENDENCE $X_{T1} = f(X_{T0})$
TRANSPORT T_1	ECONOMICAL	NO

This hypothesis was not confirmed only in relation to road freight transport.

SYSTEM IN PERIOD T_0/T_1	SYSTEM IN PERIOD T_1	DEPENDENCE $X_{T1} = f(X_{T0})$
ECONOMICAL T_0	TRANSPORT	NO

This hypothesis was not confirmed in relation to road freight transport with half-year, one-year, half and one-year and two-year delay.

SYSTEM IN PERIOD T_0/T_1	**SYSTEM IN PERIOD T_1**	**DEPENDENCE $X_{T1} = f(X_{T0})$**
ECONOMICAL T_1	TRANSPORT	YES

This hypothesis was not refused only in relation to road freight transport.

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