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SIMULATION INVESTIGATION OF CONSEQUENCES FOLLOWING FROM TRANSPORT DECISIONS

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Abstract: Different methods can be employed while investigating the consequences of transport decisions- for instance simulation methods. There are various techniques of formalizing the simulation model, from computer languages of general use and specialist simulation languages, to advanced functional simulation packages and systems. In order to illustrate the possibilities of using computer simulation model to investigate the consequences following from transport decisions, System Dynamics technique has been employed in the present article.

Keywords: computer simulation, transport decisions

INTRODUCTION

Two organizational planes can be distinguished in transport systems ([Bąkowski 1987, p. 136], [Szczepaniak 1996, p.p. 58, 173-174], [Rydzkowski & Wojewódzka-Król 1997, p. 38]), namely macroeconomic (international, national, regional) and microeconomic (transport companies, consumers of transport services). Transport decisions taken on a macroeconomic scale refer to the programming of transport system development and affect its effective functioning [Rydzkowski & Wojewódzka-Król 1997, p. 20].

Taken international plane into account, one strives after the creation of global transport market and, in order to do so, makes decisions about, for instance the harmonization of technical, environmental and socio-legal norms or the coordination of investments made in the scope of transport infrastructure of international importance [Szczepaniak 1996, pp. 187-194]. On the contrary, decisions taken on a national plane are aimed at shaping the state transport system, which consists, among other things, in the optimization of its growth as well as material development, affecting the right course of transport processes and phenomena, and influencing the development of transport companies as well as proper transport standards ([Rydzkowski & Wojewódzka-Król 1997, pp. 38-40], [Grzywacz et al. 1994, p. 18]). As far as transport companies are concerned, decisions refer mainly to tactics and efficient actions concerning [Grzywacz et al 1994, p.137]: planning production actions, financial and material means needed; reorganization and development of company, employment; organization of production and support activity. By contrast, in the case of transport users the choice of means of transport is the main decision-making problem.

Every transport decision, regardless of plain or scale it refers to, leads to certain consequences. At the level of transport companies and transport users, it is desired to receive as great economic benefits as possible, whereas at macroeconomic level, other consequences are also crucial, e.g. consequences in the scope of natural environment or traffic safety[1].

Different methods can be employed while investigating the consequences of transport decisions. Sometimes it is enough to use a simple formula in spreadsheet, yet when decisions refer to issues important to a particular transport system (e.g. development of transport company, construction or modernization of national transport infrastructure) more advanced tool is required. Computer simulation model, understood (in accordance with Martin's definition) as a logical-mathematical presentation of a notion, system or actions programmed to be solved with the use of computer, can be such a tool [Martin 1976, p.13].

There are various techniques of formalizing the simulation model, from computer languages of general use[2] and specialist simulation languages[3], to advanced functional simulation packages and systems. In order to illustrate the possibilities of using computer simulation model to investigate the consequences following from transport decisions, System Dynamics technique has been employed in the present article.

METHODOLOGICAL BACKGROUND TO SYSTEM DYNAMICS

System Dynamics (SD) is a simulation modeling method used mainly for the analysis of poorly structured problems with numerous interrelations among elements. It derives from the cybernetic approach to system analysis and allows to describe particularly complex systems in the form of interactive and combinatory

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[1] Possible consequences following from transport decisions taken at a macroeconomic level have been thoroughly discussed in [Łatuszyńska 2004, pp. 45-59].

[2] The application of languages of general use in computer simulation as well as reasons behind devising the simulation languages and their qualities have been discussed, for example in [Naylor 1975, pp. 536-544].

[3] Descriptions of different simulation languages have been provided, among other things, in [Naylor 1975, pp. 580-632]; [Tyszer 1990, pp. 101-144]; [Fishman 1981, pp. 113-152].

relations. One name which has been closely connected with SD since the 1950s is that of Forrester, who, together with his colleagues from the Massachusetts Institute of Technology (Cambridge, MA, USA), created its theoretical assumptions, based on traditional management theory, cybernetics and computer simulation ([Forrester 1971] and [Forretser 1961]).

The basis for building SD simulation models for quantitative analysis of system dynamic behaviors are stock and flow diagrams. Stock variables (also called state variables or levels) describe the states of the system, while flow variables (also called rate variables) depict the rates of change of stocks. Stocks are accumulations of their flows and are calculated as the integration of net inflows, i.e. [Sterman 2000, p. 194]:

$$Stock(t) = \int_{t_0}^{t} [Inflow(s) - Outflow(s)]ds + Stock(t_0) \quad (1)$$

with Inflow(s) and Outflow(s) denoting the values of the inflow and outflow at any time s between the initial time t0 and the present time t. Conversely, the net flow determines the rate of change of any stock, i.e. its time derivative, by means of the following differential equation [Sterman 2000, p. 194]:

$$d(Stock)/dt = Inflow(t) - Outflow(t) \quad (2)$$

It can be noticed that the stock and flow notation provides a general way to characterize any process graphically ([Coyle 2000] and [Wolstenholme 1990]). Mathematical apparatus as well as principles of modeling that conform to the convention of system dynamics have been referred to in a great number of publications[4]. Course in system dynamics is available on the Internet[5].

SD MODELS FOR INVESTIGATING TRANSPORT DECISIONS CONSEQUENCES

A wealth of evidence indicates that SD serves very well as a method for investigating consequences following from transport decisions. Examples of SD models built to support the process of transport decisions analysis have been shown in Table 1. The aforementioned models have been chosen in a more or less random way as it is difficult to refer to all information concerning the application of system dynamics in the aspect under discussion. Materials from international conference, that has been organized annually for 25 years by System Dynamics Society, are a valuable source of reference[6].

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[4] For instance Kirkwood [1998], Biniek [2002], Tarajkowski [2008], Łatuszyńska [2008].

[5] Road Maps: A Guide to Learning System Dynamics. Available on the Internet: http://sysdyn.clexchange.org/road-maps/home.html.

[6] Detailed information in the form of conference materials is available on the following website: www.systemdynamics.org.

Table 1A. SD models for investigating transport decisions consequences: microeconomic scale

Model	Model purpose and consequences investigated
Microeconomic scale	
Model for forecasting the development of railway company [Gottschalk 1980]	• analysis of the influence of implementation of solutions improving the situation of company, including: - additional government loans, - freedom of shaping transport rates, - ceasing the exploitation of railway tracks in areas losing industrial base, - the influence that the implementation of solutions increasing the productivity has on the situation of company
Model of passengers transport system [Łatuszyńska 1992a]	• analysis of the situation of transport company in conditions of growing transport needs • investigating the influence of technological changes (new types of buses) and changes in values of different elements in transport services market (e.g. fuel prices, how frequent buses run etc.) on the situation of company
Model of transport-shipping company [Miłosz et al 1996]	• supporting the process of making strategic decisions • examining the effects of different strategic decisions taken in transport-shipping company

Source: own study

To explain the possibilities of using System Dynamics for investigating consequences following from transport decisions more precisely, the example of SD model has been presented below.

SHIPPING COMPANY MODEL

The model has been construed particularly for the sake of the present paper. The model is to investigate the situation of a hypothetical small shipping company possessing one merchant ship and offering transport services between European ports. The ship is used for carrying container cargo.

The aim of the model is to answer the question about the financial possibilities of the ship owner over several dozen years. Moreover, the model enables:

- to simulate possible development of the company's fleet and reveal measurable effects of this development,
- to show the influence of some changes in the system investigated on financial results of the shipping company,
- to gain an insight into solutions adopted in the company.

The idea of the model has been illustrated on the flow and stock diagram of the model identifying the major causal effects and feedback loops between variables playing an important role in the company under consideration (Fig. 1).

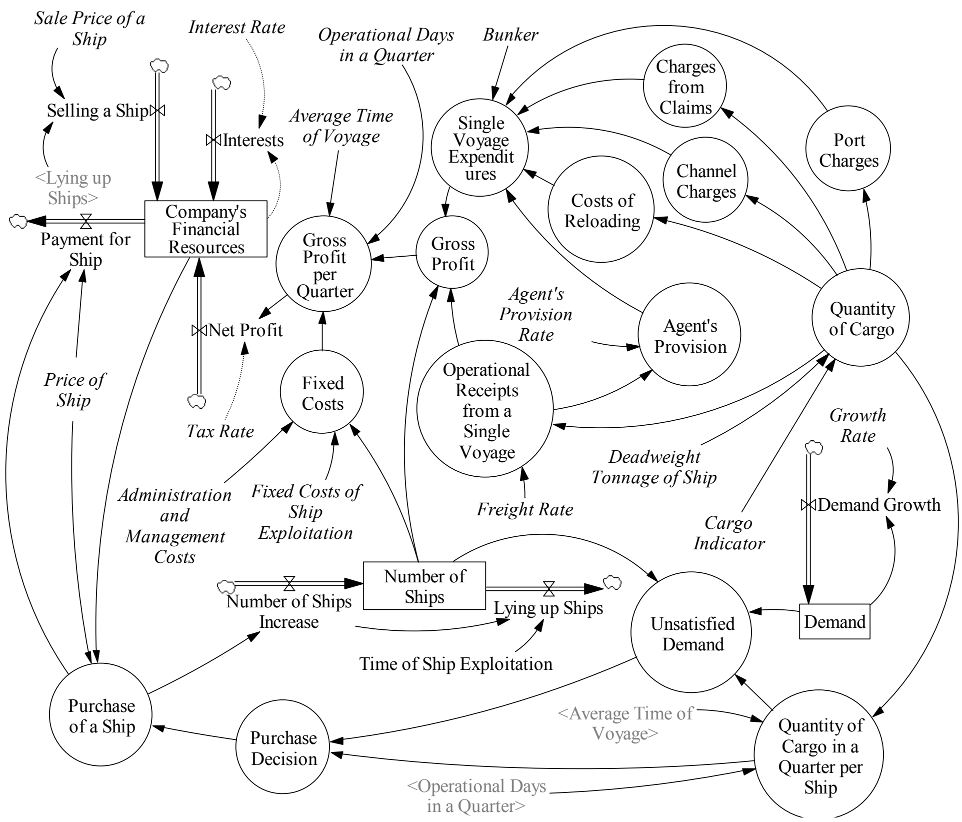
Table 1B. SD models for investigating transport decisions consequences: macroeconomic scale

Model	Model purpose and consequences investigated
Macroeconomic scale	
Model for planning international carriage of goods [Łatuszyńska 1992b]	• testing transport policy scenarios • investigating the influence of different investment variants on changes in parameters of transport system under examination, e.g. speed, transport distance, transport routes etc.
ASTRA Model [ASTRA 2000]	• long-term strategic analysis at EU level • consequences investigated: modal shifts, generalized cost of transport, time savings, transport flows in network, network load, socio-economic indicators, impact on safety and the environment
Model for the 6th Pan-European Transport Corridor [Łatuszyńska 2005]	• research on effects of development of the specific transport corridor • effects estimated: transport costs per relation, transport time per relation.
Model for the market penetration of passenger cars with new drive train technologies [Bosshardt et all 2006]	• conceptualizing the main micro processes of technological change in the Swiss car fleet • investigating the influence of new drive train technologies, focusing on natural gas vehicles (NGVs), on energy consumption
Model for examining the effects of changes in land use and transportation planning [Stave & Dwyer 2006]	• analysis of the land use system • investigating the potential effects of land use and transportation systems on air quality, traffic congestion, and other quality of life factors
Model for testing of CO_2-emissions' reduction [Grit et al 2007].	• regulatory impact assessment for the transportation sector in the case of Germany • testing legal instruments for reduction of CO_2-emissions within the transportation sector
Model of Transportation Demand Management [Vakili et al 2008]	• comparing diverse policies of Transportation Demand Management (TDM) • investigating the impact of TDM strategies in the case of Tehran

Source: own study

Due to the fact that the model has a rather cognitive than application character, certain simplifying assumptions have been made. For instance, it has been assumed that demand for services provided by amateur company is increasing, which leads to incompatibility between actual and potential transport. The incompatibility indicates that a decision about increasing the tonnage, which ship owner has at his/her disposal, can be made. If the company has accumulated essential financial means in a bank, it can buy a new means of transport – in this sense the number of ships increases and hence the fleet can carry bigger cargo. The greater the number of ships, the greater the global income from services and financial means (due to which it is more likely that the fleet will continue to develop).

Fig. 1. The flow and stock diagram of the shipping company model

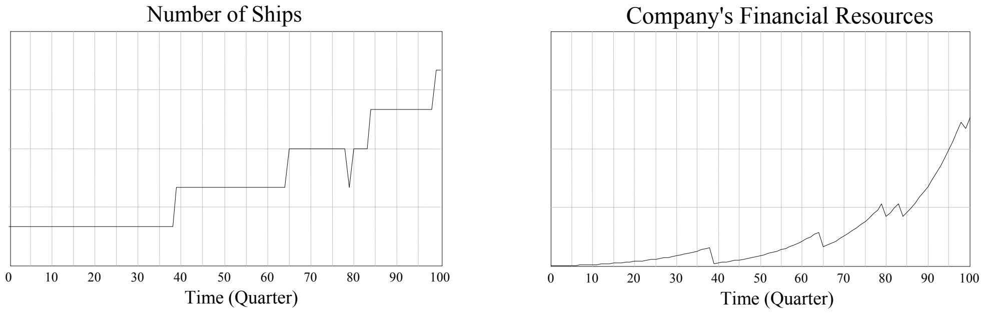


Source: own elaboration

The results of simulation experiments carried out on the model can be a source of information about the functioning of the system over time and about the influence that potential development of the fleet has on financial situation of company. It can also be used for investigating the impact that changes in parameters have on potential development and general situation of a firm.

Figure 2 shows the results of demonstration experiment that illustrate the influence of decision about increasing the tonnage (that company has at its disposal – Number of Ships) on the financial situation of company (Company's Financial Resources).

Fig. 2. Results of exemplary simulation experiment



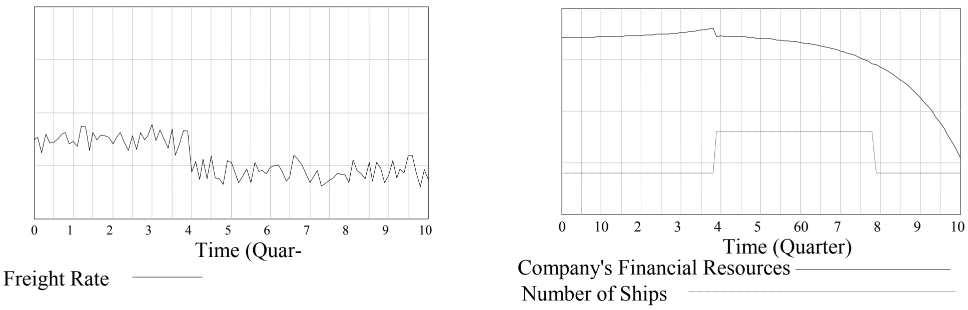
a) b)

Source: own elaboration

The experiment was done for 100 quarters. It has been assumed that the tonnage will be increased when there is proper demand for services provided by the ship owner and he/she has his/her own financial means for financing the investment. For the sake of the experiment, it has been assumed that the ship owner gets rid of 20 ships after a 20-year operation, which has been shown in Figure 2a (decrease in the number of ships in the 80th quarter). Increasing the number of ships is accompanied by increasing financial means of company (Fig. 2b), which results from higher global income, on the assumption that freight market is stable. However, another scenario can be considered, namely that freight rate will fluctuate around a certain value expected and, what is more, will drop by several points in a given moment. Figure 3 shows results obtained for this scenario. As it can be noticed, tonnage increase is not plausible and financial situation of company is worsening considerably in such a scenario.

Summing up the discussion on the model presented, it should be emphasized that the experiments done are just a simple illustration of the possibilities of examining various decision-making scenarios in a certain transport system.

Fig. 3. Results of demonstration simulation experiment



Source: own elaboration

CONCLUSION

The analysis of the hitherto existing applications of computer simulation models, i.e. for anticipating consequences following from transport decisions taken at different organizational planes, proves that these models perform well in the aspect discussed. Employing such models, one can carry out practically unlimited number of simulation experiments that allow to find out consequences following from potential transport decisions without interfering in a living organism of the system. Furthermore, a detailed analysis of simulation results enables one to understand a certain transport system in a better way and facilitates the formulation of suggestions to its improvement, which would be difficult if not impossible to reach with the use of other methods.

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Symulacyjne badanie skutków decyzji transportowych

Streszczenie: W badaniu skutków decyzji transportowych można posłużyć się różnymi metodami, w tym symulacyjnymi. Istnieją różne techniki formalizacji modelu symulacyjnego, począwszy od komputerowych języków ogólnego zastosowania, poprzez specjalistyczne języki symulacyjne po zaawansowane funkcjonalnie pakiety i systemy symulacyjne. W niniejszym artykule, w celu zilustrowania możliwości zastosowania komputerowego modelu symulacyjnego do badania skutków decyzji transportowych, posłużono się techniką dynamiki systemowej.

Słowa kluczowe: symulacja komputerowa, decyzje transportowe