

Simulation as the optimization tools for the complex logistic systems

(business, technical, IT and control systems)

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Abstract - If we conclude that the simulations are the most modern tools for optimization, it is question for real multidisciplinary problems: what kind of simulations can describe the problem?

Since logistic processes are part of larger business processes that satisfy certain society demands, in every process of planning or reengineering the ideas must be searched for at the higher level of occurrences, at the level of the stock market. At this level the simulations are applicable in the social-economic domain.

At the large corporation level (LSS - Large Scale Systems) the simulations are applicable at the level of business processes. Results of these simulations can be used to derive the project tasks for technical systems, which is subject of this paper. The first step is to analyse the material flow and logistic goodness parameter of the system that is in the planning or reengineering phase.

This analysis is the basic framework of project requirements for designing of mechanization and equipment, control systems, management of manufacture and material flows. After each level, by means of feedback, the information about how practical the whole idea and if there is a need for corrections at the previous level is received. Application of different simulation tools at the abovementioned levels will provide recommendations for further development.

Keywords - Simulation, Logistic, Optimization.

I. INTRODUCTION

Motto: A picture speaks more than 1,000 words; one model shows more than 1,000 pictures [6].

Until about 15 years ago, it was arguable to talk about simulations as an optimization method, because strictly speaking there is no goal function which streams to a certain value (max. or min.), which could give optimal values of one or a countable small number of parameters. Requirement to analyze more influential parameters or

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process models and systems that are closer to reality gives an insolvable system of equations (aim functions) and even since before last millennium, simulations have been accepted as an optimization method even with the strict authorities. Today, simulations are not just analyses of system operation and processes in the time and time related domain (for example. frequency analysis, etc.), but multiple repetitions as well, e.g. counting FEM analyses as simulations.

II. FROM GLOBAL TO LOCAL (SUBJECT AND AIM)

If we accept globalization as a process, simulations from the social-economic level support decisions that are made at the company level, and they are related to the business as well as technical system, which is the subject of this work (Fig. 1).

The aim of this paper is to point out the connection of simulations in the frame of the technical system, valuation of capability of the modern software, and especially the unsolved problems in their application.

From the commanded information level or project assignment are coming down on lower levels [8]. In technical systems there are material (goods) flows, which are the input (and the output) in/out of the business-technical system where simulations are applicable in design of logistic systems.

Parts of these systems are machines (and equipment) with information and control systems which should be projected exactly in accordance with application demands, where simulations are applied again in the designing process. As a reversible connection in all cases, hierarchically higher levels are getting affirmation of demands which are dropped to lower levels, or notification that with unfounded (extreme) demands it is not going to be possible to get a qualitative or economically lucrative solution.

In the real conditions, the decision and construction and control of machines and equipment is followed by simulations of: production, montage, functioning of new technical system or, with products of mass application of market simulation, distribution and sale etc.

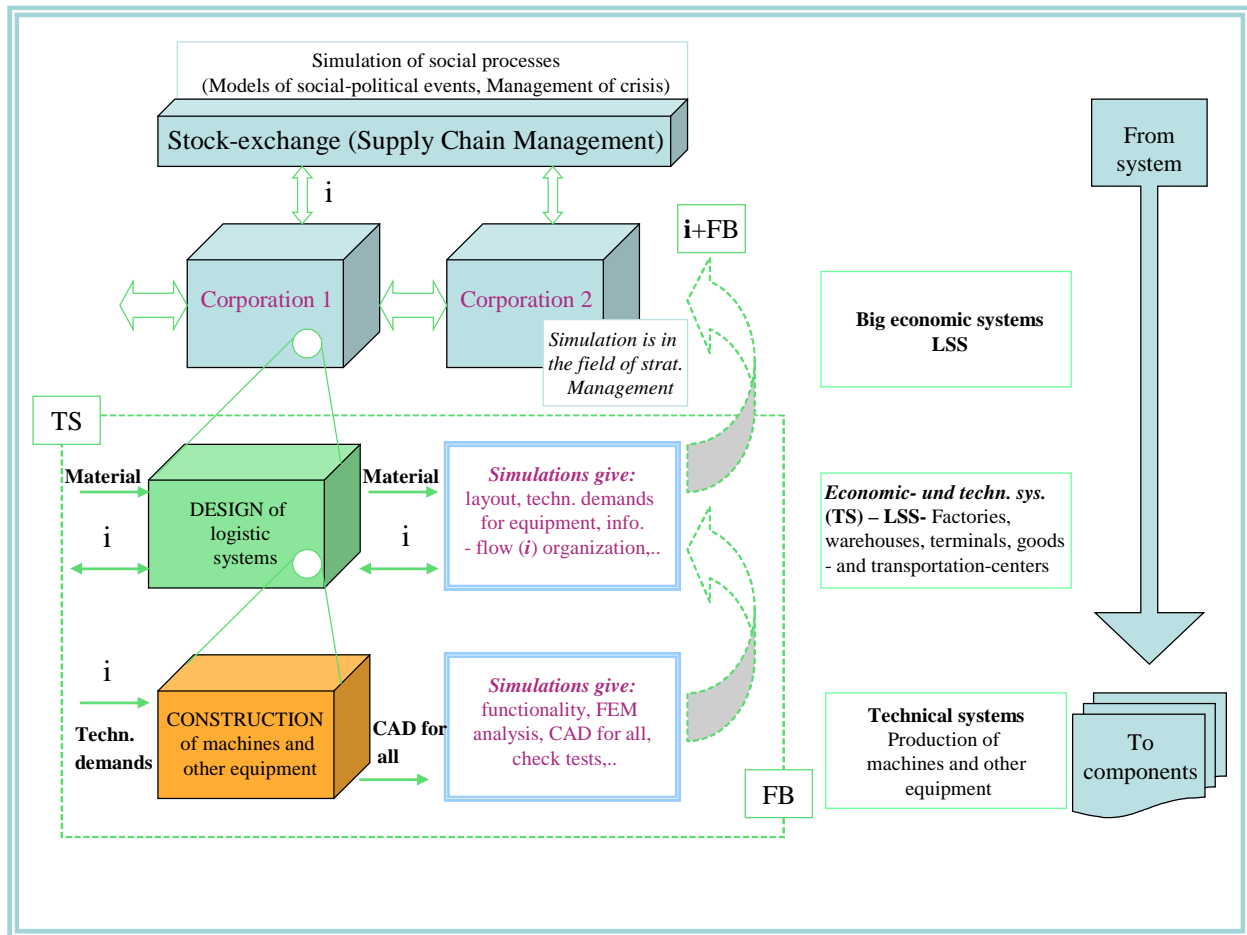


Fig. 1. Hierarchical levels of simulations (TS-Technical systems, i-information, FB-feedback, CAD-Computer Aided Design, FEM-Finite Element Method)

Since modelling is the first step in the real system analysis, Fig. 2 gives [7] key points of simulation studies, where each individually requires special research that starts from the technology of some process, followed by data analyses and the process (or machine) model, all of which need validation (comparison with previous experiences, comparison with experiments on real systems etc.) in order to be possible to approach the research - optimization of the process (or machine) through simulation experiments. Proper interpretation calls for validation of all previous operations and demands new rounds of simulation experiments until the satisfying solution is achieved in the optimization process

A. Application –Location problem and its simulation

As a consequence of permanent increase in cargo flows, there is a trend of constructing logistic canters to reduce transportation time and costs and to improve customer service.

However, costs associated with the projected technical, management and IT systems, maintenance and operation of the logistic canters increase as more of them are built. Thus determination of optimal number of logistic canters and their locations in a region can significantly contribute to the savings of transportation and storage costs, maintenance and, at the same time, high level of customer service.

Location problems consider locating a set of new facilities in a way that the transportation cost from the facilities to customers is minimized

Having in mind that a model should, as precise as possible, represent the real problem, the location model of a logistic center should be defined in accordance with the existing transport network, demand for logistic services - both in terms of quantity and location, existing infrastructural resources and cost structure of entire SC. Therefore we propose models that could be classified in a group of capacitated, network, fixed costs, location - allocation models to determine an optimal number, location and capacity of logistic canters.

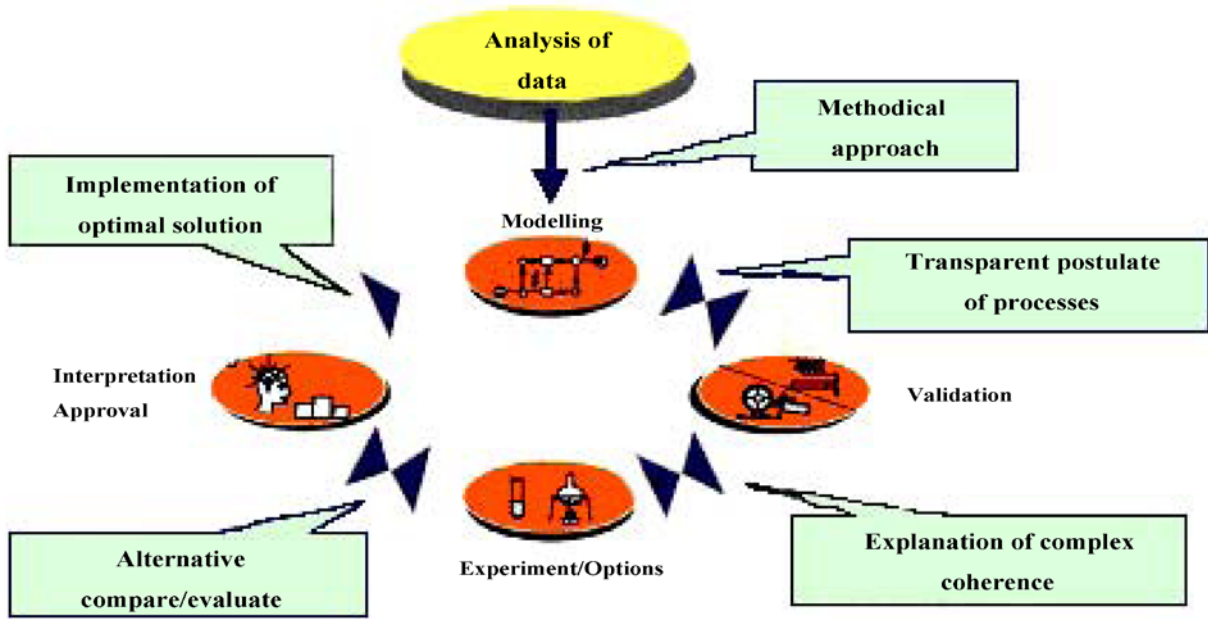


Fig. 2. Steps in a simulation's study

Based on the following inputs: i – index for supplying nodes; j – index for potential logistic centers; k – index for allocated demand nodes; w_{ij} – demand of customers in node j from the supplying node i ; w_{ik} – demand of customers in node k from the supplying node i ; s_j – capacity of potential logistic centres j ; c_j – costs for opening a center in node j per unit of capacity; f_j – capacity costs per unit of product in center j ; d_{ij} – distance between nodes i and j ; d_{jk} – distance between center j and node k ; p – number of considered centers to be opened; Y_{jj} – binary decision variable {1 if center is opened at node j , 0 otherwise}, Y_{jk} – binary decision variable {1 if node k is allocated to opened center j , otherwise 0} the logistic centers location problem can be formulated as follows:

$$\begin{aligned} \min F = & \sum_{i \in I} \sum_{j \in J} d_{ij} w_{ij} Y_{jj} + \\ & + \sum_{j \in J} (c_j s_j + f_j \sum_{i \in I} w_{ij}) Y_{jj} + \\ & + \sum_{i \in I} \sum_{j, k \in J} (d_{ij} + d_{jk} + f_j) w_{ik} Y_{jk} \end{aligned}$$

subject to:

$$\begin{aligned} \sum_{j \in J} Y_{jj} &= p, & (1) \\ Y_{jk} - Y_{jj} &\leq 0, & \forall j, k \in J, & (2) \end{aligned}$$

$$\begin{aligned} \sum_{i \in I} w_{ij} Y_{jj} + \\ + \sum_{i \in I} \sum_{k \in J, k \neq j} w_{ik} Y_{jk} \leq s_j, \quad \forall j \in J, \end{aligned} \quad (3)$$

$$Y_{jk} \in \{0,1\}, \quad \forall j, k \in J, \quad (4)$$

$$Y_{jk} \in \{0,1\} \quad \forall j, k \in J, \quad (5)$$

$$w_{ij}, d_{ij}, c_j, s_j \geq 0$$

The objective function minimizes total distribution costs of cargo flows between suppliers, logistic centers and demand nodes. The first part of the objective function considers the aggregated transportation costs from supplying nodes to the logistic centers, the second one considers the storage costs, and the last one the distribution costs from opened public logistic centers to remaining demand nodes. Constraint (1) defines that the number of opened centers equals p and constraint (2) that node k cannot be served from a non-opened center j . Constraint (3) is a capacity constraint assuring that total demand at node j and demand of all associated nodes does not exceed the capacity of center j . Constraints (4) and (5) are integral constraints.

Modelling the capacitated network location models with a fixed cost approach can be a computationally very difficult combinatorial optimization problem. This was the reason for intensive investigation of possibilities of heuristic solution procedures which run in reasonable

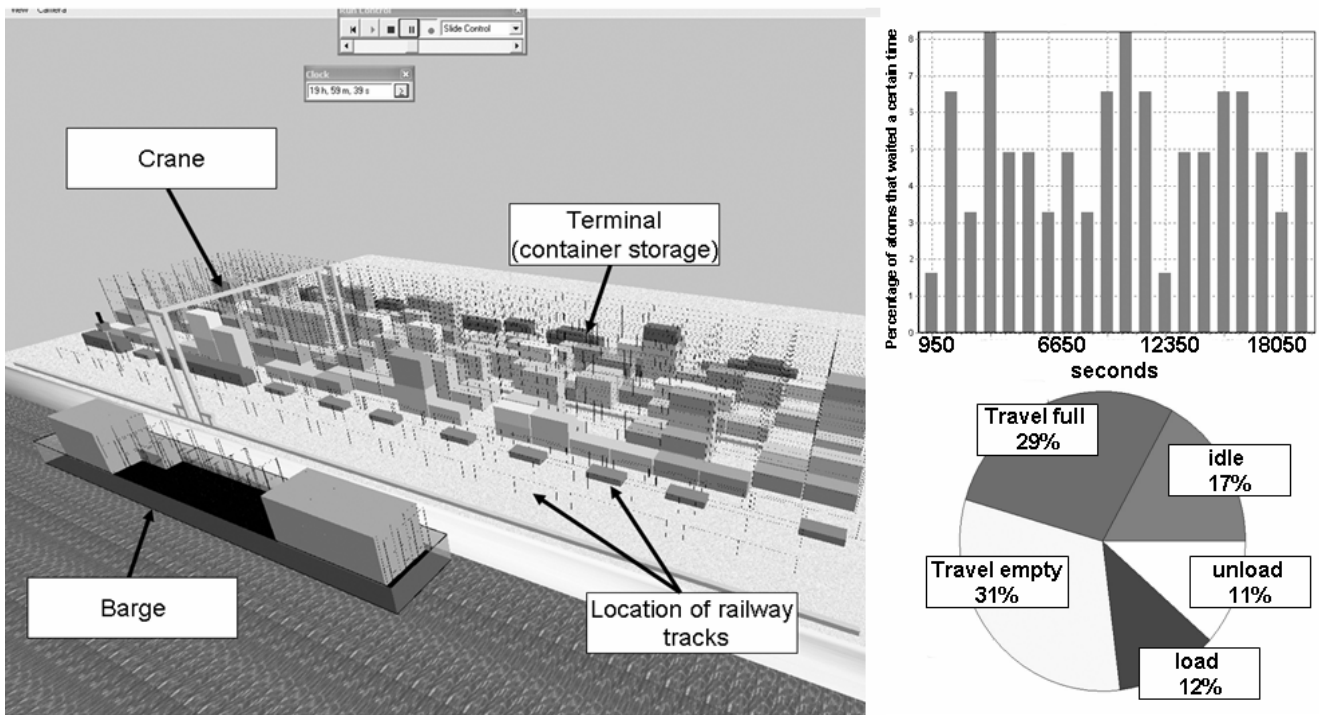


Fig. 3. Simulation of the model container terminal and output results

computer time and yield solutions of acceptable quality. Having in mind the complexity of the model we suggest application of genetic algorithms for solving the location problem. Given model is used for analysis of logistic center locations in Serbia.

B. Application - System simulation

After determination of optimal location and basic parameters of the logistic center, next step requires detailed analysis and design of that logistic center with the simulation of flows of information for the given conditions and concepts of IT systems. The first step is designing the system with simulation of material (or goods) flows, where working places are black boxes with setup and processing time, while transports and storages are the principal process parameters.

Inland container terminals are local logistic hubs for container transport to/from the customer/manufacturer. A container terminal represents a complex system with highly dynamic interactions between the various handling, transportation and storage units, and incomplete knowledge about future events. There are many decision making problems related to logistics planning and control issues of and they can be assigned to three different levels: terminal design, operative planning, and real-time control [8]. There are a large number of scientific papers that are dealing with these problems. Most of them focus on optimization of specific processes only. But optimization of each element of the larger system does not always lead to the optimization of the whole system. Nowadays, for design of

such a system, simulations are commonly used tool. By creating the simulation model, it is possible to analyze the whole system with different stochastic input and system parameters in the real time.

Here is presented an example of simulation application for determining the concept for the container terminal in river port. Performances of the models were studied under a different set of variable values (input, output and system parameters). Modelling and experimentation is done in software Enterprise Dynamics 7.

Several concepts were examined with different length of container terminal (100, 150 and 200m) and different handling mechanization (cranes, straddle carriers, reach stackers) and the level of automation in several different tasks (combination of reloading of the barges, trains and trucks). As the result, truck waiting times, container throughput, cycle times and reloading times were obtained. This data is basis for determination of the terminal design, as layout, IT and management system, capacity, where port operator has the final word. And this data is also an input data for the design of the reloading mechanization inside the terminal with its control systems.

C. Application - Construction of handling and storing equipment

Based on defined location problem as well as the design of the logistic center, requirements for mechanization intended for projected logistic center operation are obtained. Construction and optimization of handling and storing equipment are possible to achieve with the help of high value software tools for complex system static and

dynamic analysis, such as KRASTA (KRAnSTatik) and ADAMS (Automatic Dynamic Analysis of Mechanical Systems). Based on models developed in these software packages it is possible to obtain the necessary data needed for construction calculation and machine optimization, such as: forces, stress, velocity, acceleration, movement, all required in control systems as well as many other parameters.

For Control systems and database for control in the container cranes in this paper is presented the influence of kinematics of ropes upon the change of oscillating (sway) periods of container and this can be the base for choice and interaction of the control system for driving systems of trolleys and crane. If the whole crane is modelled, then on the basis of known working cycles it is possible to make database for control system. By varying of various expected masses of containers and various working cycles the concrete values are reached of electric power parameters of the driving engines of trolleys and crane, which also generate dynamic parameters and spectra of loads.

In the Figure 4 is given the model of crane of the river container terminal with following technical parameters: Span – 25 m; Outreach on both sides – 27.5 m; Lifting height – 25 m; Approximate weight – 290 t (imputing trolley of 50 t mass); Moving velocity of trolley - 2 m/s; Moving velocity of crane – 2 m/s; Lifting velocity – 0.5m/s.

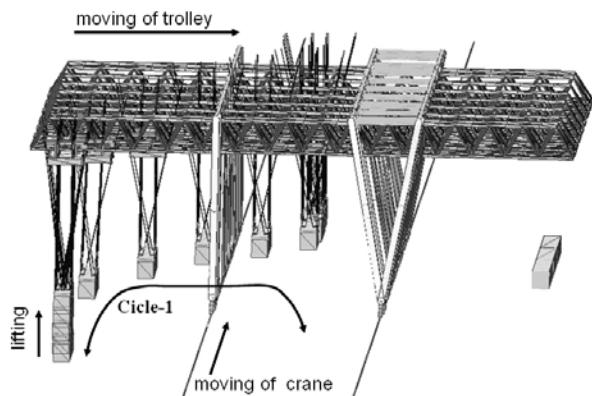


Fig. 4. Simulations of different cycles for the purpose of creation of database for control system

In Figure 5 is applied adaptive PID control for one working cycle. In the same way could also be done simulation for other cycles of work and with other masses of containers with an aim to obtain database for the control system. Due to the large number of influential parameters that are of stochastic nature, but more than 20 years individually in control systems fuzzy logic is introduced, because only these control methods can take into account the wind effect on the swing - the positioning of the container and the impact position and rocking of the ship in relation to coast [11].

After defining of the control system, by means of simu-

lations which are subject of this paper also are obtained spectra of loads for all parts of the construction for the foreseen working cycles, which result in corresponding dynamics (dynamic coefficients), which are the base for calculation of construction according to life time (fatigue).

III. CONCLUSION

Simulations as the most modern tool for optimization have plenty of possibilities, but a long-term problem remains in how to connect a number of different types of simulations that are follow one idea (problem). It is demonstrated with one example for problems in material flow logistics, starting from the location and concept of container terminals to machines operating in it, what is the basis for techno-economic analysis and what is the impact of the feedback of socio-economic analysis preceding the technical system. This approach leads to optimization of time that is spend on the developing process of a product [4], and can be named system projecting logistics.

For connection of more different simulations, required by the nature of the problem, interfaces that could transform the outgoing parameters from one simulation into incoming parameters for new following simulations are required. Further research should result in improvements of high value software, so that the large number of real cases from the practice can be included, which unavoidably includes simulations as a method for optimization - not just in the sense of technical performances, but also in the sense of rapid response to market demands for new systems, facilities or machines.

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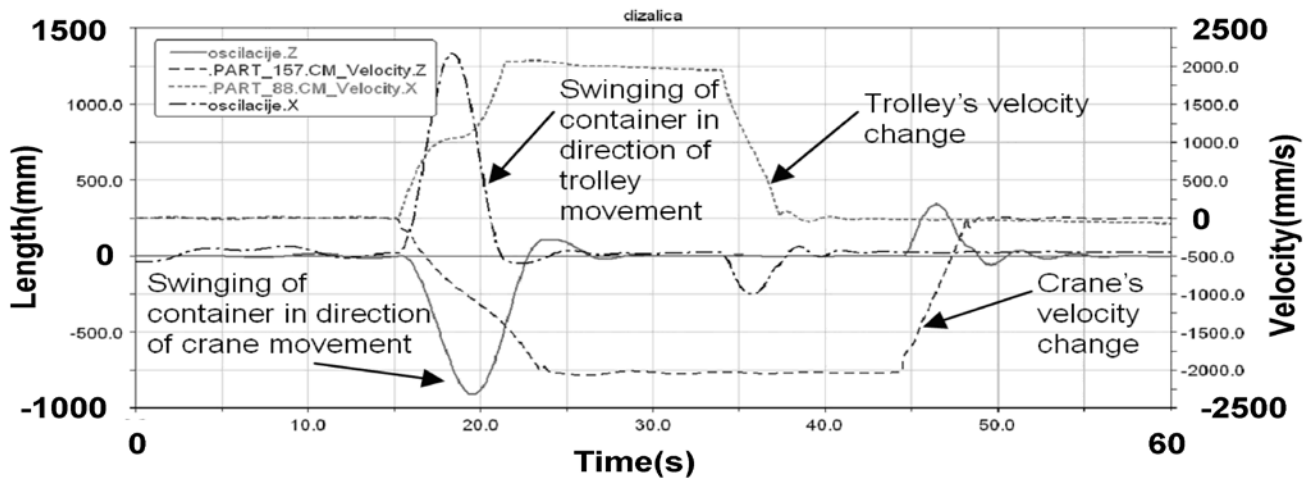


Fig. 5. Velocities and swinging of containers in relation to the trolley in real working cycles with lifting, moving of trolley and moving of crane portal (cycle in Figure 4)

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