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SIMULATIONS AS OPTIMIZATION TOOL IN DESIGN AND CONSTRUCTION OF LOGISTICS SYSTEMS - ADVANTAGES AND LIMITS

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Abstract

The paper elaborates possibilities for application of simulations as a method for optimization of logistics systems in the case of systematic – multi layer approach to the problem. Examples of material flow simulations and machine's work simulations are presented pointing out the interconnectivity and the hierarchical logic behind simulating a system and one of its elements. The simulations of an element and a system are based on entirely different mathematical methods but are certainly subject of a hierarchical influence. Additionally, within the paper, limitations in application of high valued simulation software (Enterprise Dynamics and ADAMS), are discussed.

Key words*: applied simulations, logistic systems, optimization*

1 INTRODUCTION

A picture says more than 1000 words, a model says more than 1000 pictures [1,3].

Till 15 years ago, it was arguable to talk about simulations as an optimization method, due to the fact that simulations do not include a mathematical objective function streaming to an extreme (max. or min.), providing the optimal value of one or limited number of parameters [1, 2]. However, growing demand for simultaneous analyses of more influencing parameters in a model of process flows or systems, which lead to insolvable system of equations (goal functions), led to the acceptance of simulations as an optimization method even by the side of strict authorities. Today, simulations are not just used for the analyses of processes and system operation, but for experiments as well, e.g. finite elements method (FEM) analyses are called simulations. The authors accept the definition of simulations according to the Association of German Engineers VDI 3633 and advocates for the use of the word in plural, although many use singular.

2 FROM GLOBAL TO LOCAL POINT OF VIEW

If globalization is considered as a process, business decisions are made based on the actual business environment and the current position of a company on the world market. In these circumstances, simulations provide support for the decisions making at the corporate level regarding the business and technical systems. This is the main subject of the paper (see figure 1). The main aim of the paper is to point out the relation between different levels of simulations within a technical system, evaluating the main advantages of the up to date simulation software and accentuating the limitations of high valued simulation software that should be overcome in the future.

As presented in figure 1, information (i) or project activities are transferred from the top to the lower levels. Consequently, in technical systems, material flows simulations usually represent an input for the simulations of the particular processes in the flow. At the same time, realization of particular processes in a material flow requires equipment that should be constructed directly by the processes demand. In the construction process of the equipment, simulations are also used. As feedback, in all cases, higher hierarchical levels receive a certificate of feasibility of requirement that descend to lower levels, or warnings that unfounded (extreme) requirements will not lead to a high-quality or a cost-effective solution [2].

In real conditions, after making a decision to build a business system, after designing the system and constructing the machinery and equipment, the following simulations should be executed:

- Production process for equipment and machines,
- Commissioning,
- Functioning of the new technical system, or
- Mass use of the product followed by further simulations of different markets, distribution paths etc.

According to Kramer and Necular [3], simulations are defined with SOMA tetrahedron whose angles are:

- Subject – the ones involved in the planning, designing and execution of activities,
- Object – process or a system that is analyzed and simulated,
- Means – model, hardware and software,
- Aims of simulation – e.g optimization of processes or a system.

Modeling is the first step of the real system analyses (see figure 3). Key points of simulation studies [4], start from the technology of some process, then, after data analyses, comes modeling of a process (or machine). Proper interpretation calls for validation of all previous operations and demands new circles of simulation experiments until the achievement of a satisfying solution in the optimization process.

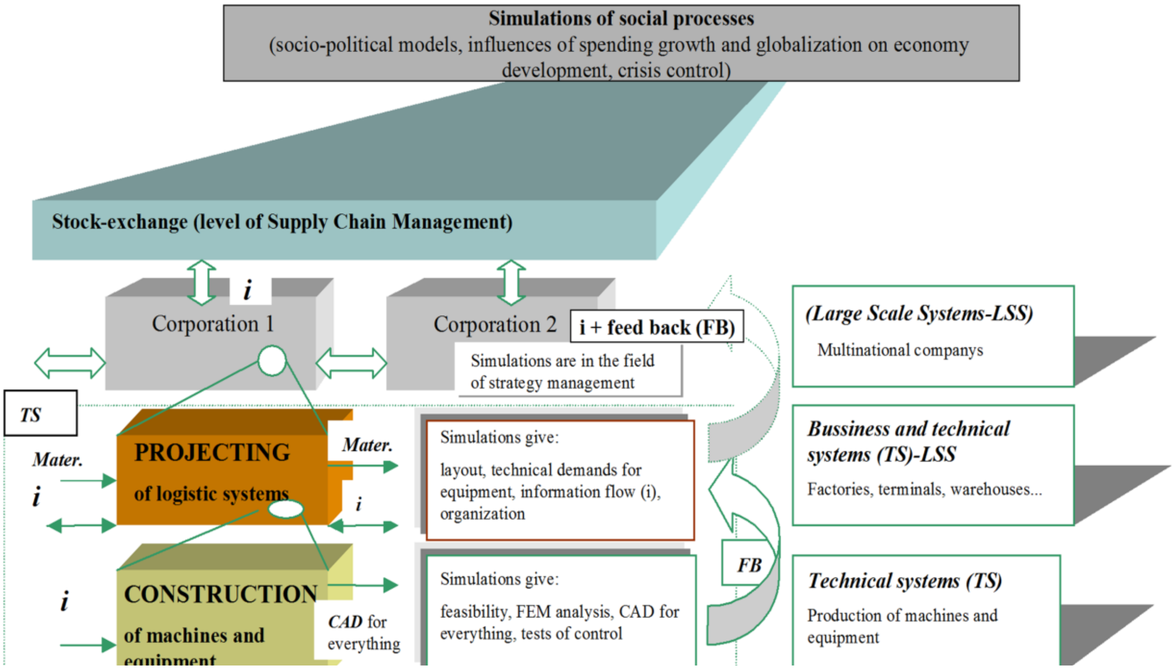

Fig. 1 *Hierarchical levels of simulations (TS-technuical systems, I-information, FB-feedback, CAD-computer aided design, FEM- finite element method)*

3. APPLICATION OF HIGH VALUE SIMULATION SOFTWARE IN TECHNICAL SYSTEMS

On the market there are high value software with incorporated broad variety of solvers and high quality graphic that enables high level of interactivity.

If it's possible to model and run simulation of a whole factory (or distribution center, or a machine with thousands of elastic pieces) on the computer screen, then there is a question about moderator (user) role. Although the software performance has significantly increase over the last 20 years, there are still some issues that require high level of user involvement:

- Feeding the simulation model with great amount of valid input data, whereat, most of the data are stochastic and taken from the previous analyses,
- How to model a concrete specific system (or a machine) with limited resources of software?

As an example, figure 4 shows a general algorithm of material flow simulation in a warehouse (input, equipment parameters in different areas and during different activities) and in a production (raw material input / semi-finished products to the hall, selection of transport routes with machines for processing Mi, which have front and back buffers, the output of semi-products and further transport to warehouses, buffers, the next phase of treatment, ...). All branching points in the figure include stochastic parameters and require application of different probability distributions [6,7].

For the machines working in the transport processes, based on the example of a forklift, a modeling concept is presented including: model of a mechanical system (construction, gear subsystem, ...), model of electrical drive and steering system (figure 5).

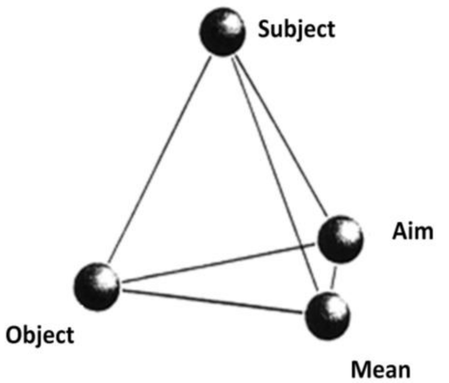

Fig. 2 *SOMA model*

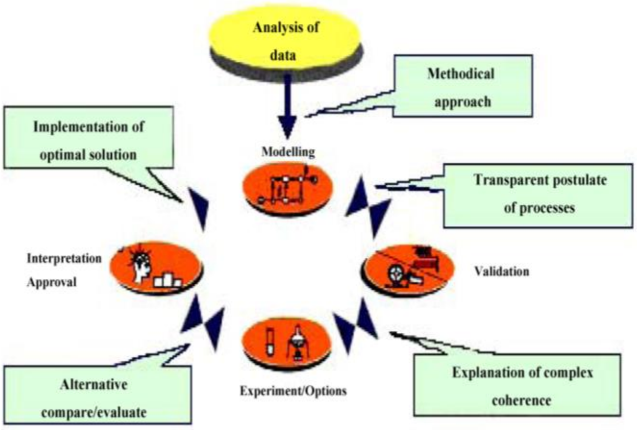

Fig. 3 *Steps in a simulations study*

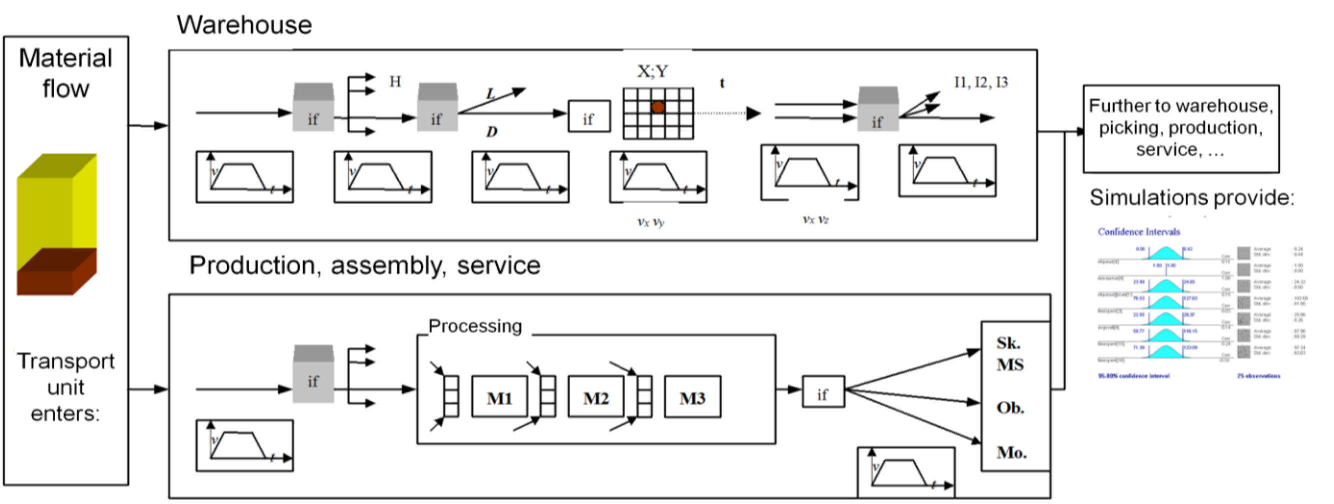

Fig. 4 *Material flows in a warehouse and in a production site*

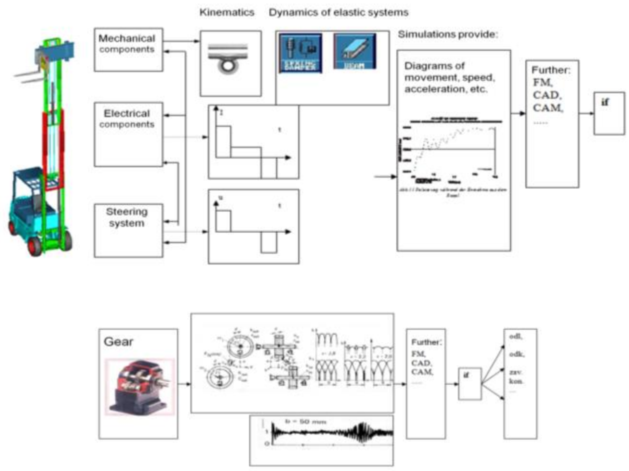

Fig. 5 *The concept of machine simulation including: mechanical, electrical ans steering components and subsystem of gears*

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4. EXSAMLES OF SIMULATION APPLICATION

4.1. Material Flow Simulations Simulation of a container terminal

Figure 6 shows a simulation model of a river port container terminal developed in the software Enterprise Dynamics (ED). The model is developed for the conditions of expected intensity of material flow and two options of terminal size: 100 x100 m and 200 x100 m. For both terminal sizes, application of two types of equipment for containers handling were analyzed: straddle carrier (see figure 6) and reach stacker.

In a real system, shipping of containers to and from the terminal can be done in three ways: by truck, by rail and by ship. Crane can take/leave container in a ship, on the quayside, in the 1. zone of the container storage area, on the rail wagon or directly on the truck (variable). During the ship unloading crane is placing containers on the quayside from where straddle carriers/reach stackers take and carry them to the container storage area. There are two zones in the container storage area (variable). Crane manipulates with the containers in the first zone and straddle carriers/reach stackers in the second zone (storing location is variable). Loading and unloading of the trucks is done by both straddle carriers and reach stackers, but load of the rail wagons can be done only by reach stackers. The assignment for the stackers and carriers is also preparation for the next ship loading and includes caring the container that needs to be sent out from the 2. zone to the 1. zone.

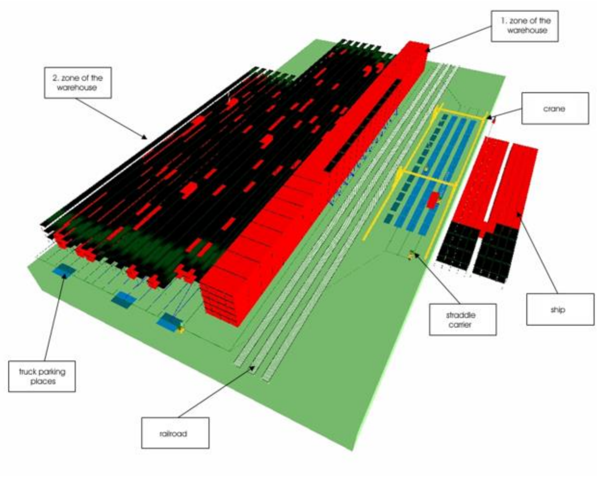

Fig. 6 *Simulation model of a river port container terminal (sofrware ED)*

Based on the simulations, maximal capacities of a terminal storage area for all four options were determined:

- 1658 of TEU in the concept 200x100 m with straddle carriers,
- 1741 of TEU in the concept 200x100 with reach stackers.

In addition to the analysis of the container handling processes, status of buffers and container storing area, simulations provided results regarding the effectiveness of all operational equipment in the terminal, providing the basis for decision making i.e. the amount of the required investment for any improvements in the future.

In this particular case, the problem in a simulation process that occurred due to the software limitations, was how to model particular elements of the system (e.g. straddle carrier which has many different functions and parameters). This problem was solved by combination of several software tools and combination of their work by many conditional commands (by applying the ED software specific programming language).

Simulation of a warehouse

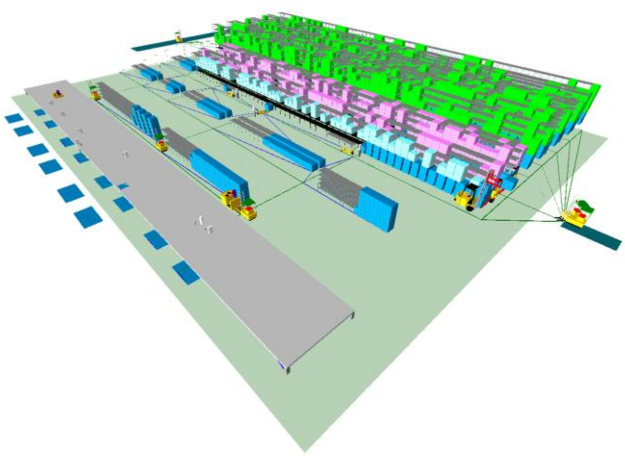

Fig. 7 *Model of the "Cash and carry" warehouse (software ED)*

Figure 7 shows a simulation model of the “Cash and carry” warehouse. The warehouse covers an area of 1075m², with 8 gates, 12 racks, 4500 pallet places and 34 units of handling equipment. The model is developed in the software Enterprise Dynamics (ED) with an aim to determine the percentage of the equipment use and to evaluate the need (justification) for implementation of RFID technology.

Simulation results provided information about the performance of every piece of equipment used, for the numerous simulation scenarios and proved cost and organizational effectiveness of the RFID application.

In the process of the simulation model development, the main issue was modeling of particular, specific system elements. In order to overcome the problem, the same as in the previous example, the ED software specific programming language had to be applied. Consequently, the modeling process was very time consuming, complicated and required advanced knowledge of the software specifics**.**

4.2. Simulations of Machine Performance Simulation of Container Dockside Srane

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.

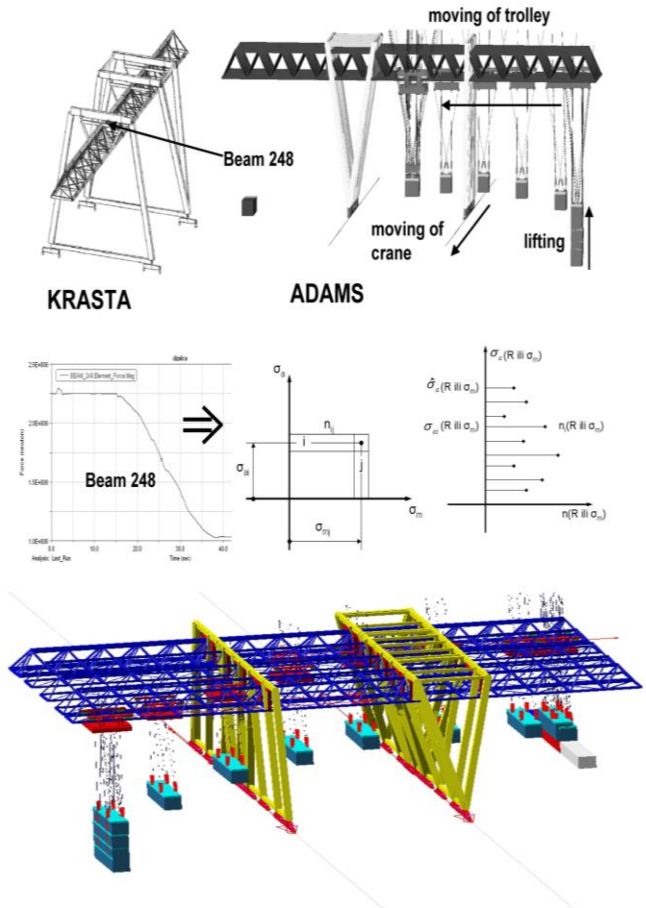

Fig. 8 *Simulation of the container quay crane and data for calculation of fatigue*

Optimization of cross sections of elements in the construction brings to lighter and cheaper constructions. Fig. 8 presents combination of data obtained from the models KRASTA and ADAMS with the aim to define collective load which is a basis for calculation of lifetime. In FEM analysis of certain parts under most impact software such as CATIA and ANSYS can be used. After acknowledging elements of the carrying construction, development of the technical documentation is significantly simplified with the help of the software AutoCAD, CATIA, and Pro/ENGINEER. Modeling of container quay cranes by varying of a range of expected masses of containers and different working cycles the concrete values of electric power parameters of the driving engines of trolleys and crane are obtained, which also generates dynamic parameters and a spectrum of loads. Obtained data can represent a basis for control systems of container quay cranes. Dynamic analysis of system parameters as real time functions, modeling extremely large and complex systems, analyzing system behavior in extreme conditions, studding the behavior of nonexistent systems etc. are all advantages of simulations and iteration of simulations with a different set of parameters is the right path to system optimization.

Simulation of Forklift

If technical requirements for a fork lift truck are taken from previous simulations, there is a question about its construction performances, so that it is adjusted to its concrete use. Figure 9 shows that simulation model in software ADAMS (Automatic Dynamic Analysis of Mechanical Systems), which is described with over 4000 differential equations (elastic are all important parts of chassis, wheels, crane with a basic frame and two masts etc.). Simulations should provide:

- Tests of control and criteria for application of active control,
- Specters of load at all important points of construction which are the basis for application of FEM analisys and constructing from the point of fatigue.

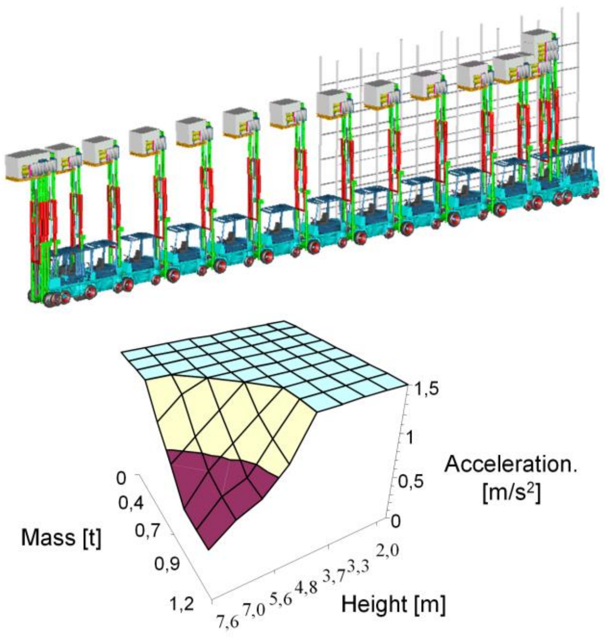

Fig. 9 *Simulation of forklift and its acceleration limits*

5. LIMITS OF SIMULATIONS APPLICATION

Apart from extremely important information about system or machine operation, there are some limits for application of simulation software in optimization purposes. Some elements of the system can be modeled easy using the existing tools within the software, some require advanced modeling knowledge so that the additional tools are created by the software user while some elements cannot be successfully modeled at all.

A. Limits of ED software

Although software ED is one of the best on the market in the field of material flow simulations, it has certain limitations with which, even with an extensive modeling knowledge, it is not possible to model certain elements or processes of a real system. The abovementioned limitations are most prominent in modeling of big warehouse systems, which contain unusual segments. As the biggest restriction, should be mentioned impossibility to place a product (pallet, container, and box) on an exactly defined location on the wall units at the time of more frequent material flow, as well as taking a product from an exactly defined location on the wall unit in the outgoing process. Consequently, there is an occurring problem with the simulation of a sorting and picking process.

Another problem can be allocated to the field of system control modeling, and it is related to the impossibility of place reservation. Namely, if there is more transport and reloading vehicles to which is assigned a task to place a product on the same location (buffer, shelf) and if there is just one free place on that location, then only the first handling unit is going to perform its assignment while others are going to stay blocked until the location is free again. To avoid that, place reservation should be implemented, more specifically, provide the information in the system by which, the moment the transport and reloading vehicle takes over a load, it will execute the "place reservation" for that same load at the location of disposal to ensure that other material handling units are directed to other locations so no eventual blockade of the equipment is possible.

B. Limits of ADAMS software

Software ADAMS, since 20 years, enables simulations of elastic mechanical systems with more movement and during the 90's of the least century it was transformed into modules adapted to special purposes, with an improved solver and a great work convenience. As a problem, there is still movement of inflexible part on the elastic part or the mutual movement of two elastic parts (e.g. see figure 9). So far the attempts to find software solutions, haven't given real answers. The author's idea is that this kind of a problem can be solved with a special algorithm which is going to correct the model in every integrating step, which transmits all parameters of the previous condition, so that the process of integration can be continued with the ascribable mistakes in calculation.

6. CONCLUSION

Simulations as the most modern tool for optimizations have plenty of possibilities, but as a lasting problem remains how to connect a number of different sorts of simulations which are following one idea (problem). It is shown by example that machine operation simulations are preceded by material flow simulations and these are preceded by simulations of business systems ect. and so all the way to social-economy simulations. Figure 10 shows the algorithm which can be the grounds for modeling and simulations in the technical systems - system modeling and machines construction. This approach leads to optimization of time that is spend on the process of a product development [11].

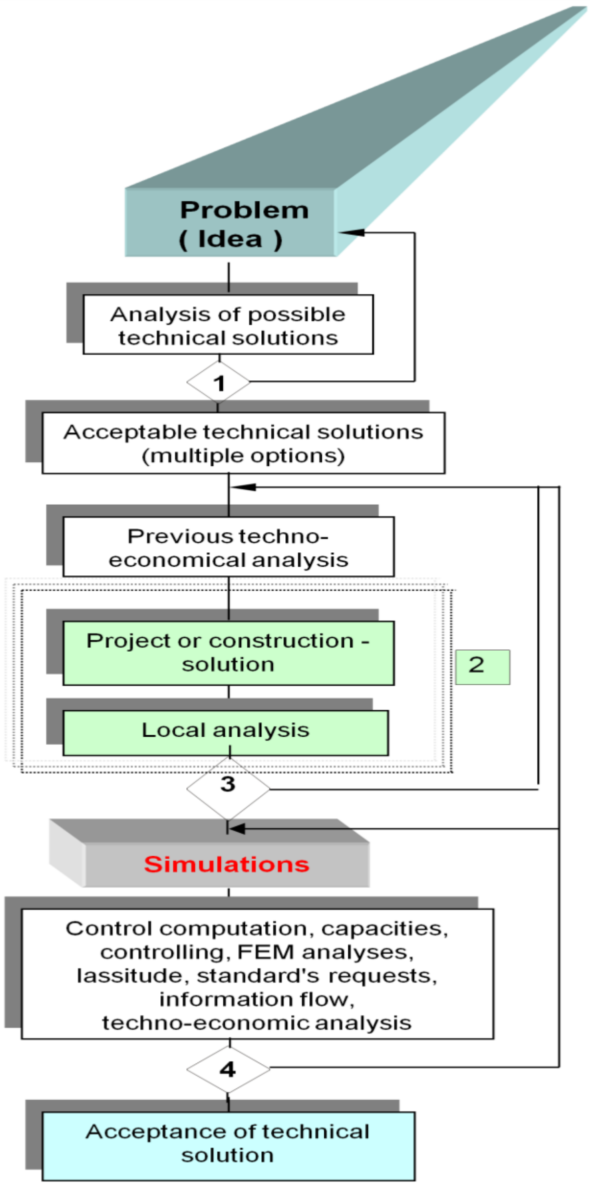

Fig. 10 *Simulation algorithm*

In order to connect more different simulations, which are required by the nature of the problem, it is needed an extensive knowledge of simulation processes, simulation software. However, if the interfaces between the software would be inproved, enabling transformation of the outgoing parameters from one simulation into incoming parameters for new following simulations, many current issues with the simulations would be resolved.

Further research should result in improvements of high value software, so that the big number of real cases from practice can be included, which unavoidably includes simulations as a method for optimizations and not just in sense of technical performances of a system, but also in the sense of rapidness of response to market demands for new systems, facilities or machines.

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