Cybernetic Formulation of Some Functions of Management – Types of Simulation and Optimization Approaches Within The System Dynamics Method

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Abstract

The purpose of this paper is to present the cybernetic formulation of some functions of management. On these grounds, the proposal for the classification of the types of simulation and optimization approaches within the System Dynamics method is presented by the author. Some of the investigation is derived from the classic works of Forrester, Coyle, Wolsterholm and others, but some constitute the author's own ideas, developed in recent years. The author welcomes any discussion on this subject.

Keywords: System Dynamics Method, Cybernetic formulation of management, Optimization and simulation within System Dynamics Method.

1 Introduction

The problem of classification of the types of simulation approaches for supporting planning and organizing in industry with continuous process, was first undertaken by the author in [11]. In this classification, the classic works of famous investigators within the System Dynamics method were contained [2–6,8–10]. But some types of the approaches constituted the author's prognosis of future work in this field. Now, ten year later, the author can say that the prognosis has come true, mainly in the area of optimization approaches. The works of prof. Coyle and the author's own ideas have developed the simulation during optimization and optimization during simulation [5, 7, 12, 13, 15].

In this paper a new classification of the simulation and optimization approaches within the System Dynamics method is proposed. The background for such classification is the cybernetic formulation of the function of management: PLANNING and ORGANIZING.

2 The author's old classification of the types of simulation investigation for supporting planning and organizing in industry

In [11] the criteria for such classification were:

– the character of modelled and simulated changes in investigated objects,

– the purpose of simulation investigation, which determines the way in which the simulation was used by people (planner, organizer),

– the role of people, as the modelled element of real and regulatory sphere of management.

The author has used the methodological divisions of research area into the following spheres: real and control (regulation) and: object and subject. Their natural interaction is presented in Figure 1.

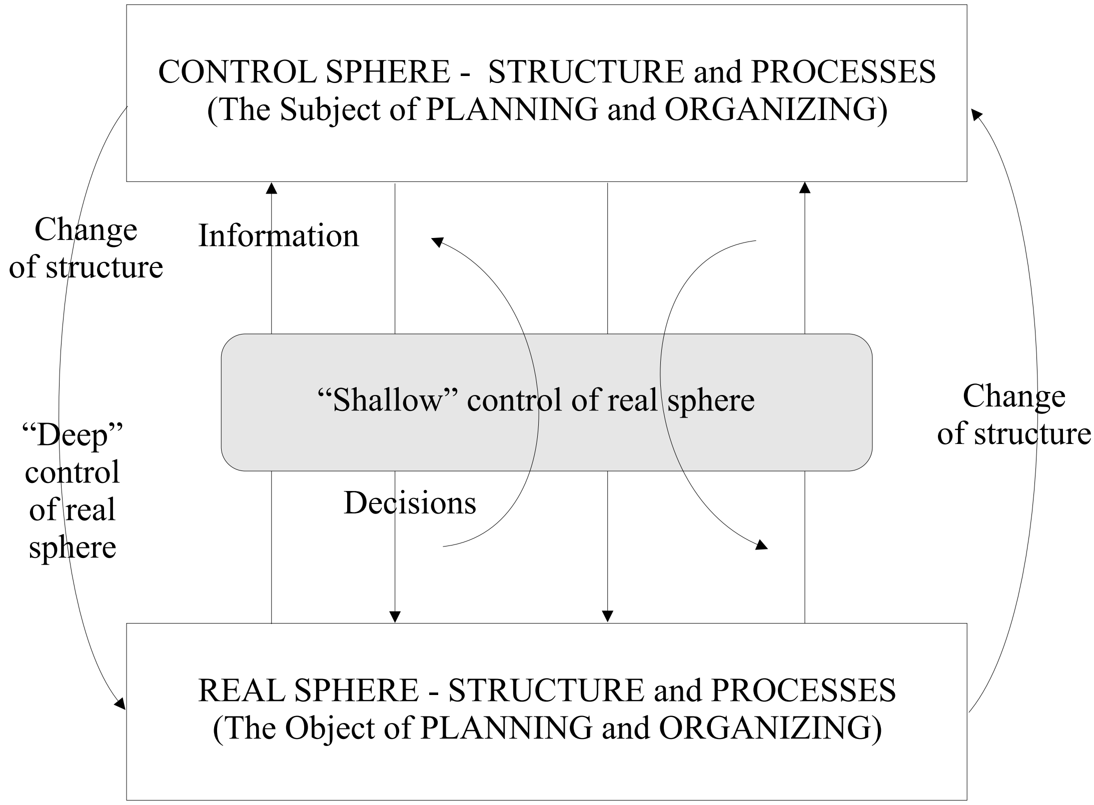

Figure 1. The interactions between real and control spheres

The author proposed the names of 19 directions of the investigation:

1^O Situation prognosis of: "what if?" type in the subject sphere of ORGANIZING (the subject is modelled as "explicit").

2^O Situation prognosis of: "what if?" type in the subject sphere of PLANNING (the subject is modelled as "explicit").

3^O Situation prognosis of: "what if?" type in the object sphere of ORGANIZING (the object is modelled as "explicit").

4^O Situation prognosis of: "what if?" type in the object sphere of PLANNING (the object is modelled as "explicit").

5^O Designing the structure of "verification of decision rules" type in the subject sphere of ORGANIZING (the subject is modelled as "explicit").

6^O Designing the structure of "verification of decision rules" type in the subject sphere of PLANNING (the subject is modelled as "explicit").

7^O Designing the structure of "verification of decision rules" type in the object sphere of ORGANIZING (the object is modelled as "explicit").

8^O Designing the structure of "verification of decision rules" type in the object sphere of PLANNING (the object is modelled as "explicit").

9^{O} Similar to 1^{O} but the subject is modelled "implicit".

10^{O} Similar to 2^{O} but the subject is modelled "implicit".

11^{O} Similar to 3^{O} but the object is modelled "implicit".

12^{O} Similar to 4^{O} but the object is modelled "implicit".

13^{O} Similar to 5^{O} but the subject is modelled "implicit".

14^{O} Similar to 6^{O} but the subject is modelled "implicit".

15^{O} Similar to 7^{O} but the object is modelled "implicit".

16^{O} Similar to 8^{O} but the object is modelled "implicit".

17^{O} Descriptive-explanative approaches in the "diffusive" sphere of real and regulation – classic System Dynamics method.

18^{O} Descriptive-explanative approaches in the "diffusive" sphere: real and regulation (with "deeper" modelling in the regulation sphere) – a modification of classic System Dynamics method.

19^{O} Descriptive-explanative approaches in the "diffusive" sphere: real and regulation (with "deeper" modelling in the real sphere) – a modification of classic System Dynamics method.

On the Table 1 author presents in syntetic form characteriscic of types of simulation investigation within System Dynamics method.

Nowadays, this classification can be supported by stricte **optimization approaches** which are contained in the direction: "verification of the decision rules". These approaches were developed by the author in the last few years. Some of them have been derived from the ideas of prof. Coyle; others are the author's own ideas (see [5–7, 12, 13, 15]). The idea of optimization approaches will be extended after the presentation of the cybernetic formulation of some functions of management, and against this background, the proposal for a new classification of types simulation and optimization approaches within the System Dynamics method.

3 The cybernetic formulation of source functions of management – types of simulation and optimization approaches within the System Dynamics model

In Figure 2 and 3 the idea of a cybernetic view of some functions of management: PLANNING and ORGANIZING, are presented. We observe the feedback loops, typical for the System Dynamics method. Presently, it is the author's proposal to interpret such loops as the types of simulation investigations for supporting the functions of management. For instance, the investigation: "what if?" in a classic loop: decisions → actions → results of actions → perception of results → perception of differences → planning tasks → decisions, support the analysis and simulation of the **situation prognosis** (see: the "old" classification, direction 1^{O} and 9^{O}). This investigations, however, offers more possibilities, for instance: taking into consideration the "disturbance of actions" or "disturbance of decisions" are the extension of the "what if?" investigation in the described loop.

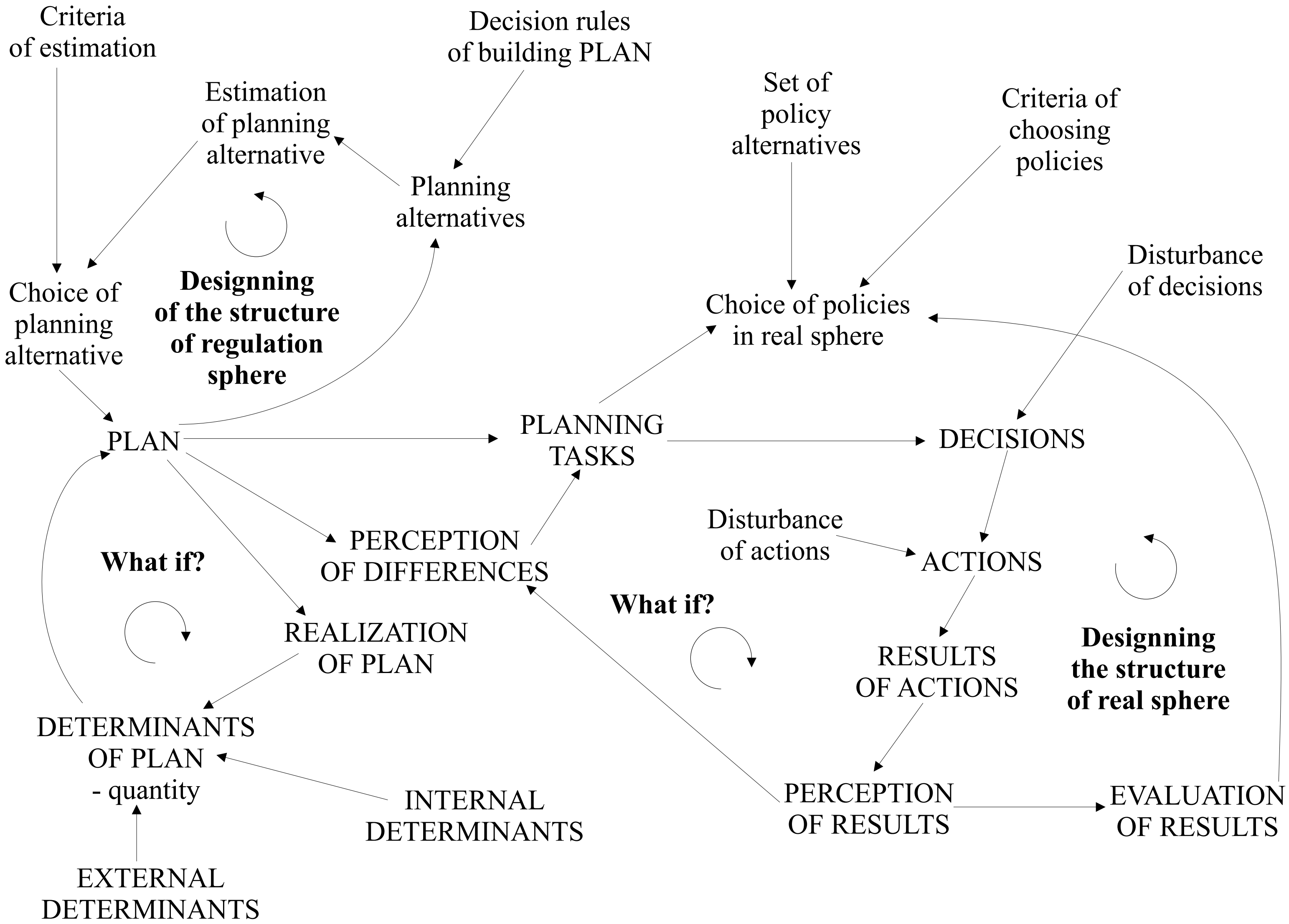

Figure 2. Feedback loops as types of simulation investigations for supporting "PLANNING" in companies

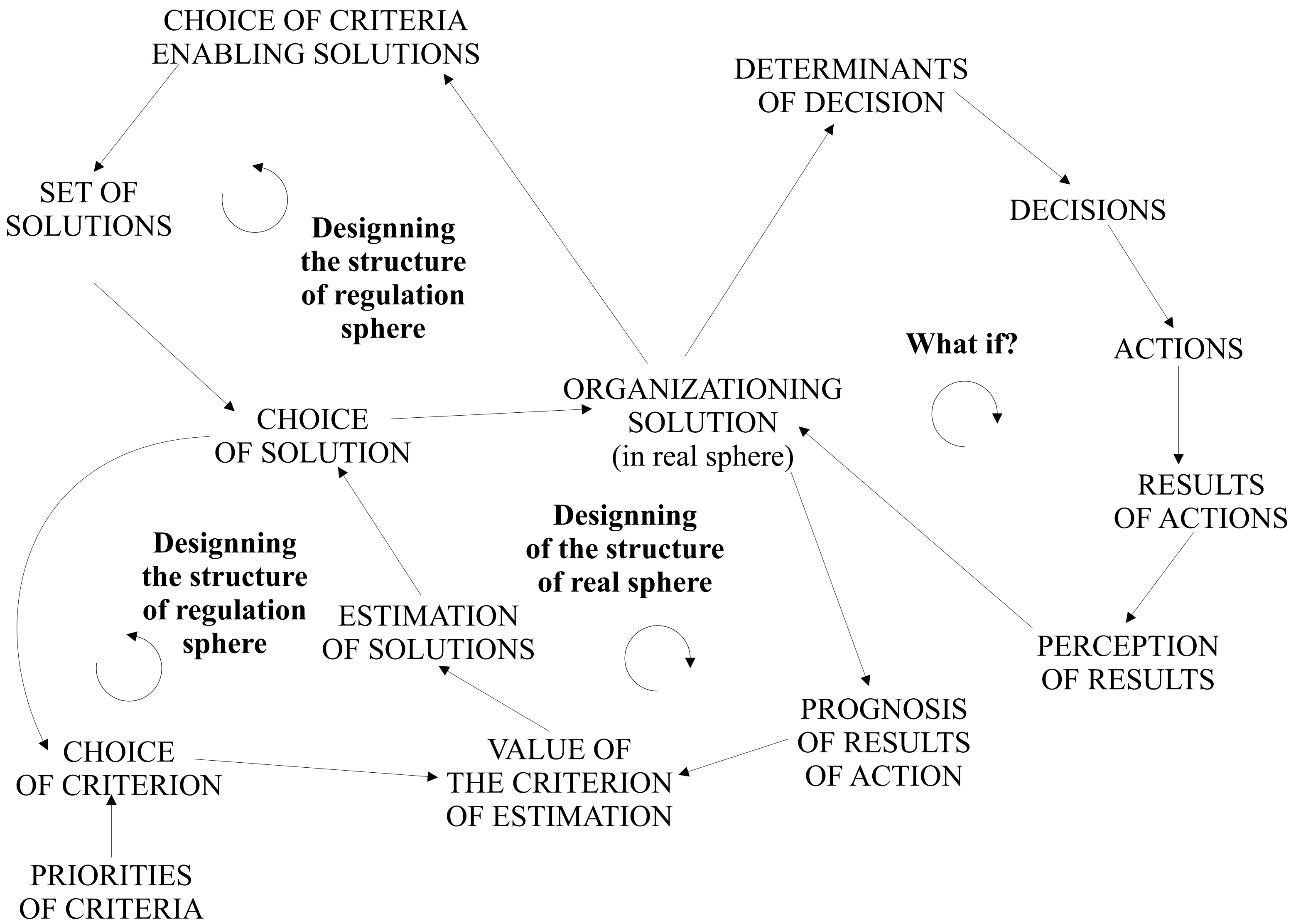

Figure 3. Feedback loops as types of simulation investigations for supporting "ORGANIZING" in companies

Another example is presented by "designing the structure of real sphere", running in the loop which contains "choice of policies in real sphere". This choice requires the: "set of policy alternatives", "criteria of choosing policies". In the classic System Dynamics model such choice tokes place **outside the model** (we can name this direction as "suboptimization"). The opposite possibility is to guide the choice "by the model", i.e. by the objective function with "the subjective sphere modelled" (man). This is the optimization in Coyle's and the author's understanding.

The author raised this subject in [12, 13, 15]. Now, the author wants to present the classification of the types of investigation within the System Dynamics method, against the background of the above mentioned cybernetic formulation of the functions of management.

The traditional directions of investigation within the System Dynamics method represent two types of approaches:

A) **The descriptive-explanatory**: the simulation model is used as a tool of the replication rules of the functioning of the system (we known the input and the output, such as the reaction of the system).

B) **The "what if?"**: the simulation model is used as a tool of the examination of the reaction of the system (with known structure and rules of functioning) when we determine the inputs of the model.

Types A) and B) satisfy, to a different degree, the needs of those who manage (plan or organize). But some needs require a different kind of simulation; such as in type C):

C) **normative**: the simulation model is used as a tool of choosing the kind and intensity of inputs to obtain the required reaction.

The scope of the normative type includes the wide range of **optimization approaches** (for instance: simulation during optimization and optimization during simulation).

It is interesting to analyze the role of man in types A), B) and C). In the case of A) human activities consist in analyzing the feedback loops, which form the structure of the system. Generally these feedback loops determine, the dynamic behaviour of the system. Such activity requires a certain scope of preparation from the human factor, who should interpret the facts, know the convention of the description of the system, etc. In other words, the expected benefits require a great deal of work.

In the case of B) the activities of man involve analyzing the times series of the observed variables of the models, which represent the effects of different inputs. Such activities occur **outside the model**. This is the so called "post simulative studies". The interpretation of the outputs requires a lot of knowledge about the system, its rules of functioning.

In the case of C) the activities of a man one limited to the formulation: the criteria of assessing the behavior of the system, the alternatives of policies rules of the scopes of parameters. Such activities require some preparation on the part of man, but they render great benefits (they consider the decision needs human).

Coming back to Figure 2 and 3, it may be noticed that the direction of the investigation "designing the structure of real sphere", require "evaluation of results", which leads to "choice of policies in real sphere". This is contained in type C), but two different consequences are possible. The "evaluation" can take place "outside the model", or "inside the model". In the first case, this is the "suboptimization study" (conducted by most of modellers of the System Dynamics), the second case is "optimization" in Coyle's sense (in the strict sense: "simulation during optimization"). New possibilities were presented in the author's investigation in [12, 13, 15].

The so called: "constrained and unconstrained optimization of the dynamics balance of production" requires "**optimization during simulation**". The main idea of such a "balance" was "solving the system of balance equation during simulation". The author has investigated so the called "pseudosolution" of differences ($M\,x = b$, at the condition $x_i \geqslant 0$). The system of the equations was created from the balance of the value of three properties of flow: mass balance ("rate of flow"), in Forrester's sense, cost balance and personal balance.

The author proposes to name this model of "optimal balance of production": as DYNBALANCE(1-3) model, because only three items are considered.

The opposite proposal is presented by DYNBALANCE(3-1) model, in which the author has considered three raw materials and one product. The article on the DYNBALANCE(3-1) model is in preparation. If possible, it will be presented in Palermo.

At the end of the paper author present Table 2 with some chosen examples of models within System Dynamics (in context of author classification of models). The author welcomes any discussion on this subject.

4 Conclusion

The author realizes that she has only have "touched" the problem, signalled in the topic of this article. The problem is wide and has many aspects. The proposal for the classification of the types of investigation within the System Dynamics method is one of may other possible formulations of the problem. The background for the idea of classification was the cybernetic formulation of some functions of management. The characteristic feedback structure has its connections with the System Dynamics method, and because of this it may be conceived as "compatible" with the main idea of the System Dynamics method.

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Table 1: Syntesis of author classifiction of the types of simulation investigation (within System Dynamics models)

Main type of study	Modelling the spheres of management and changes	The kind of modelled the man
Situation prognosis of "what if?" type (the subject is modelled "explicite" or "implicite").	Subjective sphere of PLANNING and ORGANIZING (the processes of perceiving, transfering and transforming of the information and preparing and decisions making proces); structure of informations and decisions is not changing during the experiments.	Subject is modelled "explicite" which means: clear, directly, distinctly, like the "medium" of modelled world (levels and rates of labours or clearks); when subject is modelled "implicite" if means: guessingly, supposlly.

Table 1: Syntesis of author classifiction of the types of simulation investigation (within System Dynamics models) (continuation)

Main type of study	Modelling the spheres of management and changes	The kind of modelled the man
Situation prognosis of "what if?" type (the object is modelled "explicite" or "implicite").	Objective sphere of PLANNING and ORGANIZING (the real economic processes: production, ordering, financing, investitions, etc.); structure of processes is not changing during the experiments with the model.	Object is modelled "explicite" (levels and rates of: materials, products, money, equipement, etc.); in case of "implicite the real world processes are in such high aggregation the we only "guess" the flow of information or the decision making proces, has its "material" base.
Designing the structure of "verification of decision rules" type (the subject is modelled "explicite" or "implicite").	In case of basely known study, the options of structure of decision policies are "outside" the model; so called "suboptimization" of model structure is derived by heurictic way, method "trials and errors"; structure is changing during the series of the experiments.	The regulating sphere (or "plane") is created by objective function with models managers preferencies to choose the examine options; the objective function is "inside" the model which means direct optimization of structure ("explicite" case).
Designing the structure of "verification of decision rules" type (the object is modelled "explicite" or "implicite").	The structure of real processes (for example: balance of production, balance of raw materials) is optimized during the simulation experiments; the way of optimizing is heuristic or embedding in model simulation.	See remarks in previous type.
Descriptive – explanative approaches (classic System Dynamics).	The simulation model is used as a tool of the replication rules of functioning of the system; the "diffusive" sphere of real and regulation is in different (mainly large) kind of aggregation.	This case of study is connected methodologically which type of "what if?", because we put to trial the structure of model by different inputs – in order to select the one, which has desired behaviour (which explains the real world aspect of system).
Descriptive – explanative approaches with "deepe" modelling in real or regulation sphere.	Classic System Dynamics operates very high aggregation of processes; in some casses the including of much details in model is required.	For example: very compliacted discontinuouse decision – making processes or discrete evants in real or regulation sphere (with random character of some variables).

Table 2: Some chosen examples of models within System Dynamics (in context of author classification of models)

Main type of study	Author and name of model	Description of subject and object of modelling	Some remarks and conclussions
Descriptive – explanative approaches (classic System Dynamics model).	1961 J. W. Forrester – "A customer – producer – employment system".	Structure of flows: material, raw material, orders, people, money (models of decisions which regulate the intense of flows); this is "diffusive: sphere of real and regulation.	The study with the model allows to choose the value of parameters and the structure of model (by experimentals type "trials and errors").
Descriptive – explanative approaches (classic System Dynamics model).	1971 J. W. Forrester – "World model".	Structure of flows: population, natural resources, investitions, polutions, investittions in agriculture; high aggregated model of flows and theirs connections; It contain many multipliers (tables) which models local relationships of object (real world).	The explanation of influences of sectors of model to each other-helps to study "structural sensitivity" of model; it also help investigate the influence of value of some parameters on way the world will develop.
"What if?" experiments and normative study (optimization of structure).	1996 R. G. Coyle – "Domestuic Manufacturing Company (DMC)".	Structure of flows: osders, raw materials, production; models of decisions which regulate rates of mention kinds. It has medium aggregation of polisy of real sphere of management; the model developed the objective function by formulating the equations to penalize failure to meet the target factor.	The experiments of type "what if?" preceded the optimization; they helps choose the ranges of parameters and the options of given policies to study.

Table 2: Some chosen examples of models within System Dynamics (in context of author classification of models) (continuation)

Main type of study	Author and name of model	Description of subject and object of modelling	Some remarks and conclussions
Normative study with "deeper" modelling od real and regulation sphere.	2001 E. Kasperska, E. Mateja-Losa, D. Słota.	Structure of "three dimensional" balance of production of three products from one raw material; the objective function involves three criteria with three weighting factors; these elements measures the discrepancies between the actual and target levels of "mass balance" of production, "cost balance" of production, "labour balance" of production; the deeper modelling of regulation sphere depend on creating objective function "inside the model" (not "outside" the model. like in many heurictic suboptimization experiments on the field).	Two kinds of optimization were performed a) optimization embedding in simulation on System Dynamics models; b) simulation embedding in optimization (in Coyle's sense); the optimization experiments help to choose the optimal structure of production of three items; the point of deeper modelling of real sphere is that three different items from one raw material is modelled, which has better conections with real economic world.

Back to the Top