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Extended Sensitivity Analysis of Parameters and Structure in System Dynamics Models – Some Case Study

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Abstract
The problem of sensitivity analysis of parameters and structures in System Dynamics models is rather new for field modelers. The possibilities of packet COSMIC and COSMOS allows to apply extended sensitivity analysis not only of parameters of the simulation models but structures of these models too.

1 Introduction

Analysis of the changing of the values of the parameters in simulation model type System Dynamics [1–6, 14] is one of the fundamental stage of building such a model. Detection of set of, so called, sensitive parameters of the model is not easy in case of complex, nonlinear, dynamical and multilevel systems. First prof. Coyle has undertaken this problem and proposed the tool for analysis (see [1–4]). Authors have applied the idea of prof. Coyle and extended the evolutionary aspect of such analysis, specially in the context of process of learning (see [13]). In paper some new results with using COSMIC and COSMOS are presented and some conclusions about subject of consideration are drown.

2 Extended Sensitivity Analysis of Parameters and Structure – Case Study

Three different kinds of analysis were applying to the model DYNBALANCE (3–1–III). First analysis was, so called, Direct Optimization, that allows to choose the optimal value

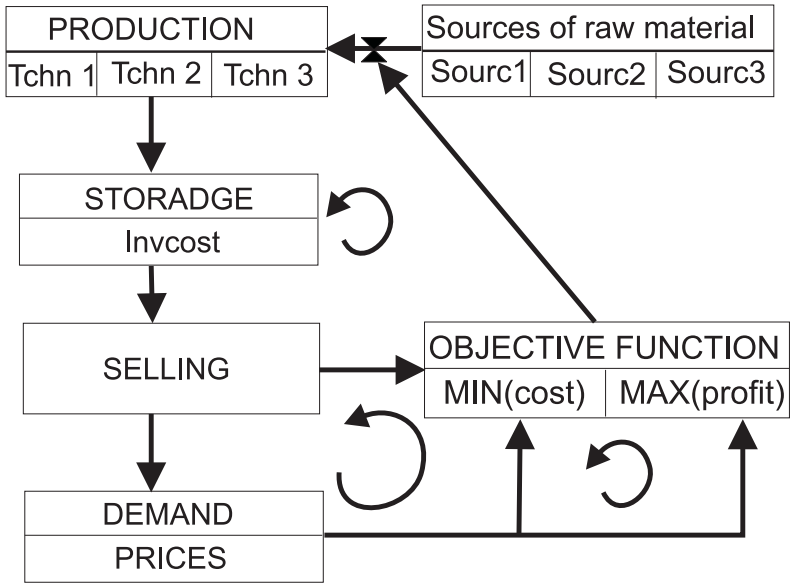

Figure 1: Simplified idea of the structure of model DYNBALANCE (3–1–III)

of searching parameters, which optimized the objective function. Second analysis was: Base Vector Analysis that allow to test the sensitivity of parameters in model in context to improving the value of objective function. Third analysis was, so called, Simplification, which try to find simpler model structure.

The model DYNBALANCE (3–1–III) was created by Kasperska and is one from the family of models type System Dynamics, associated with problem of balancing of raw materials and production (see [9–13]. The general structure of model, in illustrative form the reader can see on Figure 1.

The model contains some levels, which accumulate the production and store and such information like: losse of profit, cost of raw materials, cost of production. The objective function consists of the total cost of production and "penalty" factor (accumulation of the cost of the inventoring of product, accumulation of lose of profit). The "penalty" has weights factors, which modelled the preferences about contributing of items of the penalty to final value. It is also possibly to apply different objective function: profit from sell and the aim will be searching to maximize it. In next section the results of some experiments will be presented in undertaken context of consideration.

3 Some Results of Sensivity Analysis on Model DYNBALANCE (3–1–III)

Below authors present the main results of experiments, mentioned three kinds: Direct Optimization, Base Vector, Simplification.

Table 1: The main results of experiment 1

parameters	final value	original value	lower limit	upper limit
ucr1	50.000	100.000	50.000	100.000
ucr2	50.000	50.000	50.000	100.000
ucr3	10.000	10.000	10.000	100.000
tchn1	15.280	20.000	0.000	40.000
tchn2	39.866	10.000	0.000	40.000
tchn3	39.999	20.000	0.000	40.000
ucpr1	200.000	500.000	200.000	500.000
ucpr2	200.000	500.000	200.000	500.000
ucpr3	100.000	100.000	100.000	700.000

Initial value of "fob":	$0.29128E+08$
Final value of "fob":	$0.2098E+08$
Final value of inventory:	260.60
Final value of price:	1118.1
Final value of penalty:	$17.5640E+06$
Final value of demand:	253.50

Experiment 1

The set of searching parameters was rather large. In optimization dialog we assume:

- number of iteration: 100
- value of step multiplier: 0,3
- length of simulation: 100 weeks.

After 100 iteration we have obtained the results presented in Table 1.

It will be interesting to compare the results of this Direct Optimization with next experiment, so called, Base Vector Analysis.

Experiment 2

In this experiment, like the "active parameters" was chosen: $tchn1$, $tchn2$, $tchn3$ and after 100 iteration we have obtained the results presented in Table 2.

Comparing the final value of objective function in both experiment (1) and (2) we can see that this value in Base Vector is worse to value in Direct Optimization. Probably there are others sensitive parameters in model (not only: $tchn1$, $tchn2$, $tchn3$).

Table 2: The main results of experiment 2

parameters	final value	original value	lower limit	upper limit
ucr1	55	100	50	100
ucr2	50	50	50	100
ucr3	10	10	10	100
tchn1	32	20	0	40
tchn2	22	10	0	40
tchn3	32	20	0	40
ucpr1	500	500	200	500
ucpr2	500	500	200	500
ucpr3	100	100	100	700

Initial value of "fob":	$0.29128E+08$
Final value of "fob":	$0.25939E+08$
Final value of inventory:	244
Final value of price:	1118.10
Final value of penalty:	$20.8607E+06$
Final value of demand:	253.50

Experiment 3

The assumptions and main results of experiments type "simplification" are presented in Table 3. The accepted values of parameters in simplification type Y (see [1]) gives better results then in type X.

4 Final remarks and conclusions

The purpose of the paper was to present some results of experiments considered the problem of extended sensitivity analysis of parameters and structures in some model type System Dynamics. Final remarks are as follows:

- the Direct Optimization allows to choose the optimal value of searching parameters, which optimized the objective function,
- the Base Vector Analysis allows to test the sensitivity of parameters in model in context to improving the value of objective function,
- the Simplification try to find simpler model structure,
- the evolutionary aspect of sensitivity analysis (both: parameters and structure) can't be overestimated; in building, simulation and testing models of complex, dynamical, nonlinear systems this aspect seem to be of great importance (the scope of paper not allow to develop this problem). We plan to undertake it in near future.

Table 3: The main results of "SIMPLIFICATION" for maximization

type of Simplification	PARAMETERS			
	Simplified parameter		Ordinary parameters	
	initial value	final value	initial value	final value
type X	$\alpha = 0.3$ $\beta = 0.3$ $\gamma = 0.3$	$\alpha = 1$ $\beta = 1$ $\gamma = 1$	$tchn1 = 0.40$ $tchn2 = 0.40$ $tchn3 = 0.40$	$tchn1 = 38.800$ $tchn2 = 39.986$ $tchn3 = 39.997$
value of objective function: $0.184 + 08$			(initial: $0.513 + 06$)	
type Y	$\alpha = 0.5$ $\beta = 0.5$ $\gamma = 0.5$	$\alpha = 0$ $\beta = 1$ $\gamma = 0$	$tchn1 = 23.200$ $tchn2 = 39.849$ $tchn3 = 39.849$	
value of objective function: $0.191 + 08$			(initial: $0.614 + 07$)	

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