Multicriterion choices in System Dynamics – some way of modelling and simulation

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Abstract : The purpose of this paper is to present some way of modeling and simulation of the multicriterion choices in System Dynamics method. This problem is strictly connected with so called "optimization embedded in simulation" and "simulation embedded in optimization". An interesting point of view is to analyzing, modeling and simulation decision-makers preferences in real economic situations. Many interesting examples of the structure of the objective function, with so called weight factors, will be presented. On the base of models: DYNBALANCE(1-3), DYNBALANCE(3-1-III), DYNBALANCE(2-2) will be illustrated how the optimization can change locally or globally the structure of the SD models. At the end some conclusions about the subject of consideration will be formulated.

Résumé : Nous allons présenter une façon de modéliser et simuler les choix multicritères en Dynamique des Systèmes. Ce problème est très fortement lié avec ce qu'on appelle "l'optimisation au sein d'une simulation" et "la simulation au sein d'une optimisation".

Une approche intéressante consiste à analyser, modéliser et simuler les préférences des décideurs dans des situations économiques réelles. On montrera de nombreux exemples intéressants de structure de la fonction objectif, avec des facteurs de pondération. Se basant sur les modèles DYNBALANCE (1-3), DYNBALANCE(3-1-III), DYBALANCE(2-2), on montrera comment l'optimisation peut changer localement ou globalement la structure de modèles dynamiques.

On suggèrera à la fin quelques conclusions concernant le sujet traité.

1 Introduction

The decision-making issue is one of the great importance in the field of System Dynamics method. Analyzing, modeling and simulation of the way of making the decisions in the system, were the central point of interest for researchers. This problem is strictly connected with so called "optimization embedded in simulation" and "simulation embedded in optimization"[1][2][3][4][5][6][7][8]. Still there are too little papers that concern these problems, specially in the aspect of the decision-makers preferences in real economic situations.

[1] Kasperska E., Mateja-Losa E., Słota D. (2000). *Some extension of System Dynamics method - theoretical aspects.* Proc. 16th IMACS World Congress, M. Deville, R. Owens, ed., IMACS, 718-10, 1-6.

[2] Kasperska E., Mateja-Losa E., Słota D. (2000). *Some extension of System Dynamics method - practical aspects.* Proc. 16th IMACS World Congress, M. Deville, R. Owens, ed., IMACS, 718 -11, 1-6.

[3] Kasperska E., Mateja-Losa E., Słota D. (2001). *Some dynamics balance of production via optimization and simulation within System Dynamics method.* Proc. 19th International Conference of the System Dynamics Society, J. H. Hines, V. G. Diker, R. S. Langer, J. I. Rowe, ed., SDS, 1-18.

[4] Kasperska E. (2002). *Cybernetic formulation of some functions of management - types of simulation and optimization approaches within the System Dynamics method.* Proc. 20 International Conference of the System Dynamics Society, P. I. Davidsen, E. Mollona, V. G. Diker, R. S. Langer, J. I. Rowe, ed., SDS, 1-11.

[5] Coyle R.G. ed. (1994). *COSMIC and COSMOS. User manual.* The Cosmic Holding Co.

[6] Coyle R.G. (1996). *System Dynamics Modelling. A Practical Approach.* Chapman & Hall.

[7] Kasperska E., Mateja-Losa E., Słota D. (2002). *Optimal dynamical balance of raw materials - some concept of embedding optimization in simulation on system dynamics models and vice versa.* Proc. 20th International Conference of the System Dynamics Society, P. I. Davidsen, E. Mollona, V. G. Diker, R. S. Langer, J. I. Rowe, ed., SDS, 1-23.

Last couple of years Kasperska was inspired by the ideas of prof. Coyle and has studded the examples of his models with objective functions. She, with her colleagues : Mateja-Losa and Słota, has started to build the models in the stream of "optimization". Such efforts not only applied the ideas of prof. Coyle but extended the issue of changing globally or locally the structure of SD models.

The "family" of models, named: DYNBALANCE (1-3), DYNBALANCE (3-1), DYNBALANCE (3-1-III), DYNBALANCE (2-2), were created by Kasperska and many experiments were performed by her colleagues. Now authors want to pay special attention to problem of modeling the objective functions, analyzing their structures and the consequences for multicriterion choices in some SD models.

2 Multicriterion choices in System Dynamics – some way of modeling and simulation

One of the simplest form of objective function was created by Kasperska in paper, describing the model DYNBALANCE (1-3). The structure of this model is presented on figure 1.

The objective function "fob" is consisted of three elements with, so called: weight factors (w_1, w_2, w_3). First element: *SFFTB*, measures the fitting of total balance (mass balance) during the whole horizon of simulation. Physically, this element is mapping the differences between the actual possibilities of production (technology) and these from calculated optimal plan *(α, β, γ)*. The second element, represents the fitting of cost balance (*SFFCB)* during the whole horizon of simulation. And the third element measures of the fitting of labour balance. The main structure of the simple program is presented below.

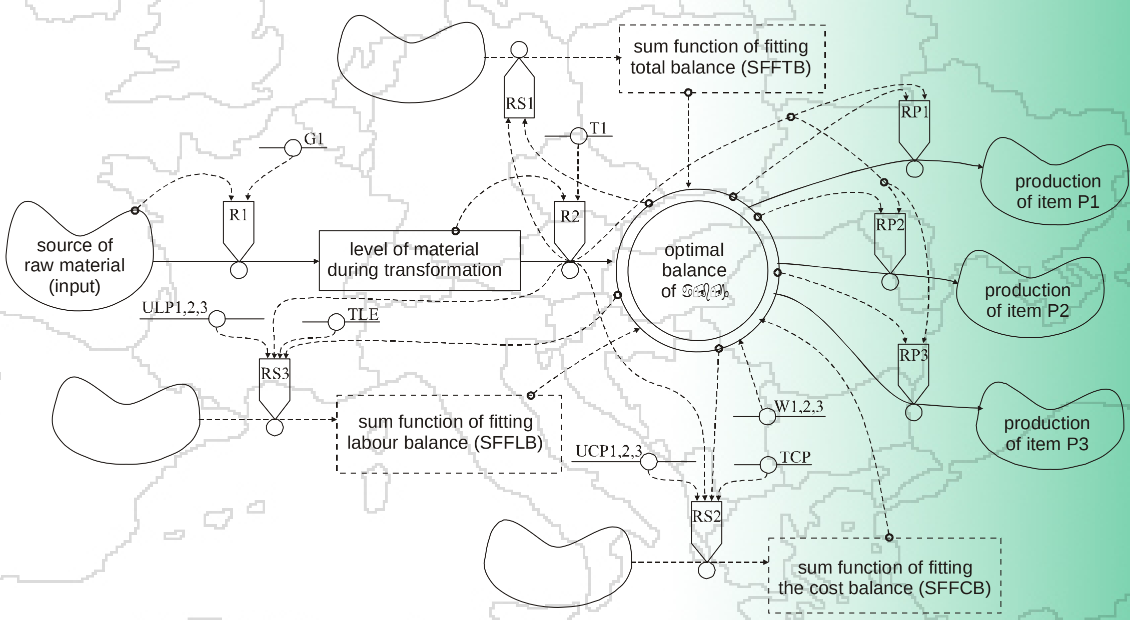

Figure 1. Optimal dynamics balance of production (from paper[3])

* Model DYNBALANCE (1-3)
Lmt.k=lmt.j+dt(r1.jk-r2.jk)*

[8] Kasperska E., Słota D. (2003). *Two different methods of embedding the optimization in simulation on model DYNBALANCE(2-2)*. Proc. 21st International Conference of the System Dynamics Society, P.I. Davidsen, E. Mollona, V.G. Diker, R.S. Langer, J.I. Rowe, ed., SDS, 2003, 1-23.

```
r1.kl=input.k*g1
r2.kl=lmt.k/t1
input.k=po+p1*SIN(6.283*time.k/perd)
fob.k=w1*sfftb.k+w2*sffcp.k+w3*sfflp.k
rs1.kl=(1-alfa-beta-gamma)*ar2.k
ar2.k=lmt.k/t1
rp1.kl=alfa*ar2.k
rp2.kl=beta*ar2.k
rp3.k=gamma*ar2.k
rs2.kl=tcp-rp1.kl*ucp1-rp2.kl*ucp2-rp3.kl*ucp3
rs3.kl=tle-rp1.kl*ulp1-rp2.kl*ulp2-rp3.kl*ulp3
sfftb.k=sfftb.j+dt*(rs1.jk-rs.jk)
sffcp.k=sffcp.j+dt*(rs2.jk*rs2.jk)
sfflp.k=sfflp.j+dt*(rs3.jk*rs3.jk)
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In paper[3] authors assumed many cases of balance (unconstrained and constrained). For example, in constrained balance of flows is: $\alpha + \beta + \gamma = 1$. This condition denotes full accordance of the actual production (of three items) with optimal value of their production. Addition of penalty function was required what has resulted in the occurrence of discrepancies from the condition $(\alpha + \beta + \gamma = 1)$. When the condition is not fulfilled $(\alpha + \beta + \gamma < 1$ or $\alpha + \beta + \gamma > 1)$ the massive penalty factor named *kara* is added to the value of the base function *fob*.

Technically speaking it has a form of:

$$penalty = kara * \max(0, abs(\alpha + \beta + \gamma - 1)).$$

The extension of such "penalty" factors, authors applied, for example, in paper[9], in model DYNBALANCE (3-1-III). Its structure is presented on figure 2.

[9] KASPERSKA E., MATEJA-LOSA E. (2005), *Simulation embedded in optimization – a key for the effective learning process in (about) complex, dynamical systems,* ICCS 2005, LNCS 3516, 1040-1043. Springer Verlag Berlin Heidelberg.

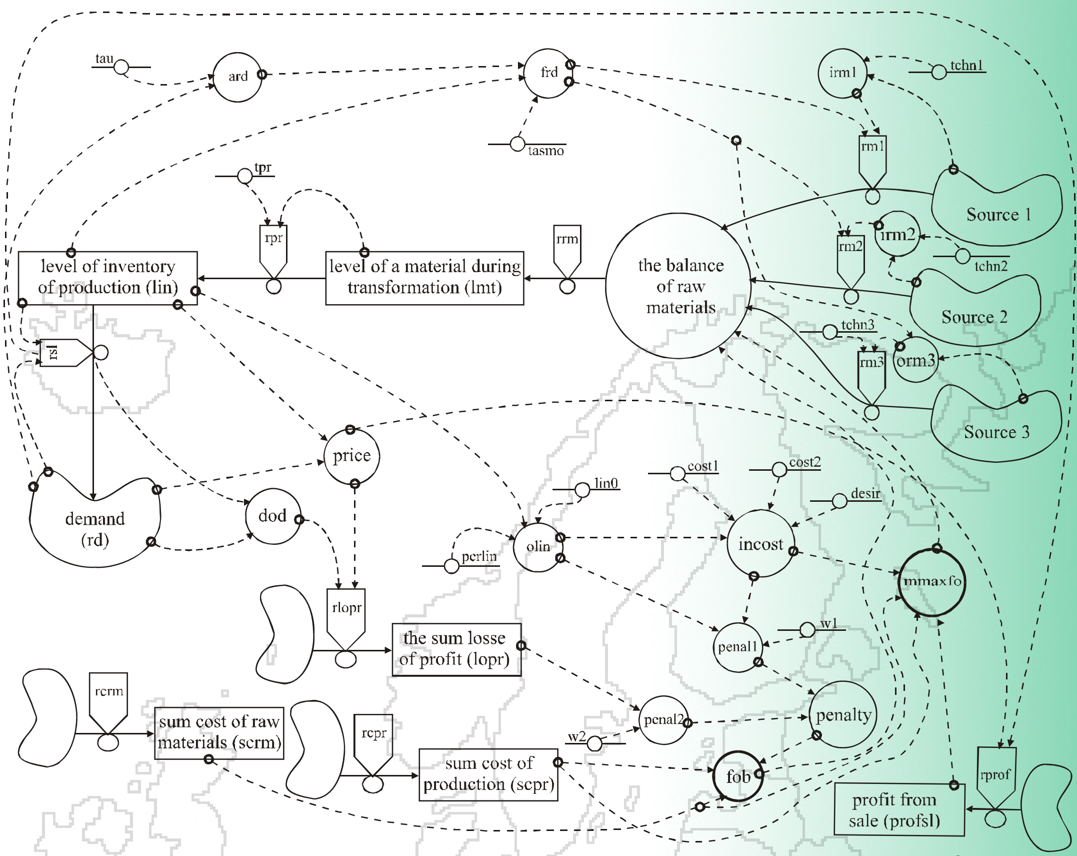

Figure 2. Structure of model DYNBALANCE(3-1-II) (from paper[9])

The choices in both objective functions:

- The *"fob"* for minimalization
- The *"mmaxfo"* for maximalization,

had taken into consideration the multicriterion objectives. Lets demonstrate the fragment of program, in COSMIC[5] language, connected with functions: *fob*, *mmaxfo*.

```
a fob.k=scrm.k+scpr.k+penalty.k
a penalty.k=penal1.k+penal2.k
a penal1.k=lincos.k*w1
a penal2.k=lopr.k*w2
a invcost.k=clip(cost2,cost1,olin.k,desir)
a olin.k=sample(lin.k,perdlin,olin0)
c olin0=300
c perdlin=2
c lin0=100
c cost1=10
c cost2=15
c w1=25
c w2=1
a maxfob.k=profsl.k-maxpen.k
a mmaxfo.k=maxfob.k-scpr.k-scrm.k
a cofprk.k=scpr.k+scrm.k
l profsl.k=profsl.j+dt*rprof.j
n profsl=0
a rprof.k=rsl.k*price.k
a maxpen.k=lincos.k*w3
c w3=1
```

We can see, that function „*fob*" takes into consideration, not only the cost of production but the penalty factor ("penalty"), with measure the cost of inventorying, and the cost of losse of profit from sale.
These both elements of the penalty have theirs weight factors (see: *w1*, *w2*, *w3* in program). These weight factors mapping our preferences for meaning elements of function, for estimation the goodness of accepted optimal value.

The possibilities of measuring these preferences in models type SD are practically unlimited. In classical structure of SD models, the "simulation embedded in optimization" changes globally the structure. It means that calculated values of optimized parameters are accepted in the whole horizon of simulation (except the case of optimization in so called "PLANNING HORIZON" –see Coyle).

However, in case of "optimization embedded in simulation", for example on model DYNBALANCE(2-2)[10], the accepted values of optimized parameters, are changing in each step in simulation. Such "locally" optimal solution can be confronted, in the context of dynamic of the system like the whole (in horizon of simulation). Lets see, the structure of such system on figure 3.

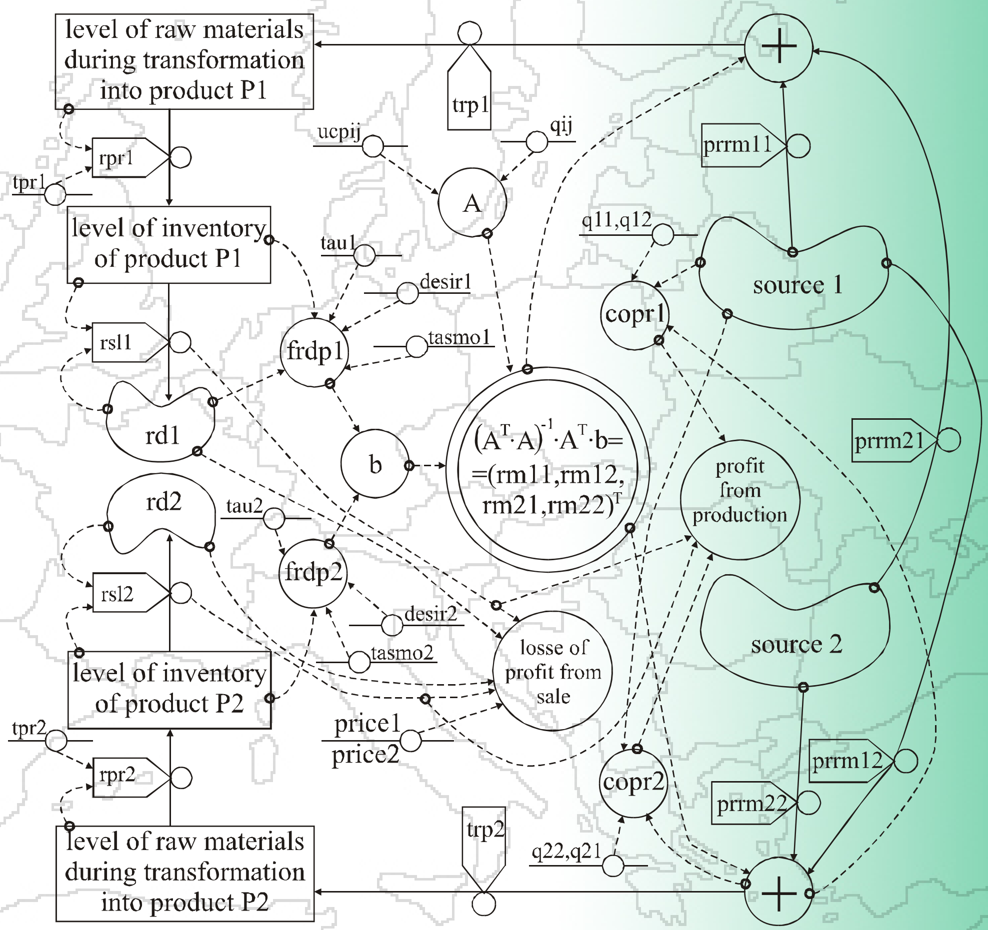

Figure 3. Structure of model DYNBALANCE(2-2-c) (from[10])

[10] KASPERSKA E., SŁOTA D. (2005), *Optimization embedded in simulation on models type System Dynamics - some case study*, ICCS 2005, LNCS 3514. 837-842, Springer Verlag Berlin Heidelberg.

The idea of solving the matrix equation (1):

$$\begin{pmatrix} q11 & 0 & q12 & 0 \\ 0 & q21 & 0 & q22 \\ 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 \\ ucp11\cdot q11 & 0 & ucp21\cdot q12 & 0 \\ 0 & ucp12\cdot q21 & 0 & ucp22\cdot q22 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} rm11 \\ rm12 \\ rm21 \\ rm22 \end{pmatrix} = \begin{pmatrix} frdp1(t) \\ frdp2(t) \\ sourc1(t) \\ sourc2(t) \\ b5 \\ b6 \\ b7 \\ b8 \\ b9 \\ b10 \end{pmatrix} \quad (1)$$

uses the method of finding the so called "pseudosolution", which minimize the norm of overdetermined equation (1). This is Euclidean norm , so it is the square root of sum of squares of discrepancies $(Ax-b)$; for $i=1,2,\ldots,10$. So, the found solution is that give the best "fitting" of balance (1). The scope of the paper can't demonstrate the many different possibilities of extension of this model (taking into consideration different objectives of fitting balances type (1)). So, time for the conclusions.

3 Final remarks and conclusions

The purpose of the paper was to present some way of modeling and simulation of the multicriterion choices in System Dynamics method. This problem was strictly connected with both: "simulation embedded in optimization" and "optimization embedded in simulation". Final conclusions are as follows:

- The decision-makers preferences can be modeled by the use of many objectives (taking into consideration weight factors).
- The "multicriterion" elements of objective functions, help to measure the goodness of accepted optimal value (objective function and parameters), in different aspects of consideration.
- The proposed optimal solutions change globally or locally structures of SD models, giving on many ways the chances to study the dynamic of the system and its complexity.