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Improving the collaborative network performance through the activation of compatible strategies

Beatriz Andres*
Centro de Investigación en Gestión e Ingeniería de la Producción (CIGIP).
Escuela Politécnica Superior de Alcoy, Universitat Politècnica de València. Centre d'Innovació i Investigació. Calle Alarcón, 1, 03801 Alcoy (Alicante)
E-mail: beaanna@cigip.upv.es
*Corresponding author

Raul Poler
Centro de Investigación en Gestión e Ingeniería de la Producción (CIGIP).
Escuela Politécnica Superior de Alcoy, Universitat Politècnica de València. Centre d'Innovació i Investigació. Calle Alarcón, 1, 03801 Alcoy (Alicante)
E-mail: rpoler@cigip.upv.es

Beatriz Andres is a PhD student in Enterprise Engineering and Production PhD program at the Universitat Politècnica de Valencia (UPV) funded by *Programa VALi+d per a Investigadors en Formació* from Valencian Government. She is member of Research Centre on Production Management and Engineering (CIGIP) from UPV. He is also member of the Association for the Organisation Engineering (ADINGOR) and the Society of Collaborative Networks (SOCOLNET). Her current research focuses on the areas of Collaborative Networks, Non-Hierarchical Manufacturing Networks, Decentralised Decision Support, Supply Chain Modelling and Strategies Alignment.

Raul Poler is Full Professor in Operations Management and Operations Research at the Universitat Politècnica de Valencia (UPV). He received his PhD in Industrial Engineering in 1998. He is Director of the Research Centre on Production Management and Engineering (CIGIP). He has led several Spanish Government and European R&D Projects. He has published a hundred of research papers in a number of leading journals and international conferences. He is the Representative of INTERVAL (the Spanish Pole of the INTEROP-VLab). He is member of the Association for the Organisation Engineering (ADINGOR) and the IFIP WG 5.8 Enterprise Interoperability. His key research topics include Enterprise Modelling, Collaborative Networks, Knowledge Management, Production Planning and Control and Supply Chain Management.

Abstract. Establishing collaborative relationships among the enterprises belonging to a network encourages them to jointly work in order to achieve common objectives that cannot be achieved if they work in isolation. The participation in collaborative networks involves enterprises to define their own objectives and subsequently, to identify the strategies whose activation promotes positive influences in all the objectives defined by all the networked partners. Nevertheless, in real networks, contradictions among the objectives defined by the enterprises may appear due to the heterogeneity that characterises its members. Accordingly, a model that supports the identification of compatible strategies is developed, based on the system dynamics method. The model takes into account that the strategies designed in one enterprise should promote the achievement of the objectives defined by other enterprises of the network. The identification of compatible strategies will allow the attainment of the objectives, and consequently increase the levels of the network performance.

Keywords. Compatible strategies, collaborative network, KPI, performance management, objectives achievement, alignment

1 Introduction

Over the last years collaboration has been widely studied due to the advantages associated. The formal definition of a collaborative network is given by Camarinha-Matos and Afsarmanesh (2005) as a variety of entities that are largely autonomous, geographically distributed and heterogeneous in terms of their operating environment, culture, social capital and goals. In an effort to gain a better understanding on the ways of managing collaboration various studies have been developed (Camarinha-Matos et al., 2009; Andrés and Poler, 2013). In collaborative networks, the partners' relationships evolve from competition to collaboration by not only exchanging the information but also performing joint business and working together to achieve compatible goals. Moreover, different degrees of collaboration can be achieved, depending on the relations established, the degree of objectives and strategies alignment and the amount of information shared (Converge Project, 2010).

Establishing collaborative relationships implies obtaining competitive advantages among the enterprises that participate. The benefits associated with collaboration are on the one hand, the reduction of risks, costs and time-to-market; and on the other hand, the increase the market share, assets utilization, skills and knowledge and improve customer services (Poler et al., 2013). Definitely, through collaboration, the involved entities achieve common goals and increase their stability and sustainability.

Despite the advantages associated with collaborative networks a significant percentage of them fail (Bititci et al., 2007). Many are the reasons why enterprises fail when they take part in a collaborative network, such as (i) lack of commitment and sharing goals, (ii) lack of aligned strategies (iii) absence of mutual trust (iv) inadequate agreed practices and values, (v) difficulties in participants' relationships, (vi) dissatisfaction with the collaboration outcomes and (vii) internal conflicts, amongst others.

Collaborative networks allows enterprises to jointly work in order to achieve common or compatible objectives, that without establishing collaborative relationships would never be achieved due to the higher costs associated if an enterprise individually works (Camarinha-Matos and Afsarmanesh, 2005). Accordingly, the strategies defined to achieve these objectives have to be necessarily aligned. Considering, the importance of aligning the strategies defined by the network members and the advantages obtained when collaborate, this paper focuses its work in addressing the limitations that enterprises have when sharing goals and defining compatible or aligned strategies.

Due to the success of collaborative networks largely depends on the achievement of higher degrees of strategies' alignment (Andres and Poler, 2014a), this paper leads to identify for each network partner the set of strategies that allow optimising the objectives of all the partners forming the network in order to obtain an optimised network performance. In the light of this, this paper is organised as follows: the problem of strategies alignment is defined in section 2. As the model developed to deal with the strategies identification is based on the system dynamics methodology, section 3 gives a broad view of this methodology in order to give the reader a better understanding of the model developed. After that, the model that allows identifying the proper strategies, whose activation results on obtaining higher levels of performance in the collaborative network is provided; giving support in the decision making of strategies alignment process (section 4). The paper ends in section 5, providing the reader the main conclusions derived from the developed model and giving future research lines to be developed in further work.

2 Description of the Problem

Collaborative networks are characterised by consisting of various autonomous enterprises and it may occur the situation in which one enterprise takes part in more than one network. In this case, each enterprise defines its own objectives and in order to achieve these objectives, each enterprise formulates its own strategies. Therefore, it is very likely that some of these partners have contradictory objectives. Hence, for the set of collaborative enterprises, it can be observed that the defined objectives and the strategies formulated by one enterprise, to achieve those objectives, could favour, or not, the objectives and strategies of other enterprises. In order to achieve a sustainable and stable, collaborative network enterprises should be able to identify those strategies whose activation promotes the improvement of the objectives defined by other enterprises belonging to the network, in other words, to identify compatible strategies.
An exemplary situation would be one in which the objectives of one enterprise promote the achievement of the objectives defined by other companies in the network and the strategies defined by one network partner are aligned with the strategies of other networked partners (Andres and Poler, 2014a) (figure 1). Nevertheless, this ideal situation is very difficult to achieve due to the heterogeneity of the objectives and the strategies to achieve them, so that a situation in which a strategy has negative influences on the attainment of the objectives defined by other networked enterprises, can be seen.
Therefore, for enterprises belonging to a collaborative network the defined objectives and the strategies formulated by one enterprise, to achieve those objectives, could favour, or not, the objectives and strategies of other enterprises. In order to achieve the ideal situation, collaborative network enterprises belonging to a collaborative network should be able to identify those strategies that among them are compatible and whose activation promotes the improvement of the objectives defined by the networked enterprises (Andres and Poler 2014a).

[Figure 1. To appear here]

In management field, the compatibility of strategies is known as the strategies alignment. The strategies alignment concept is defined as the combination of the strategies of all the partners forming the network in order to fulfil the defined objectives. The strategies alignment enables to appropriately identify those strategies that have positive influences in the objectives of all the networked partners (Andrés and Poler, 2014b). Different authors have treated the problem of strategies alignment over the last years. Hereafter, a summary of the most relevant and recent works is provided.

Piedade-Francisco et al. (2010) identify the set of decisions that significantly influence on the strategies' alignment, such as partners' selection, contract agreements, objectives definition and performance management systems design. Performance measurement and management methodologies are suggested in the literature to deal with the strategies alignment process among the partners (Piedade-Francisco et al., 2010; Verdecho et al., 2010). From the point of view of relating the performance management with the strategies alignment, Andrés and Poler (2014a) develop a model through measuring the key performance indicators (KPIs) to identify the set of strategies that favour the objectives achievement. This model allows researchers to identify the strategies that are aligned within the collaborative partners considering the increase rate of the measured KPIs when a certain strategy is activated in an enterprise. Considering this, the work developed in this paper is a continuation of the research started in Andrés and Poler (2014a) and an extension of the work developed in Andres and Poler (2014b). Thus, a model that allows identifying the strategies to be activated is provided in order to improve the achievement of the objectives at enterprise level and the performance at network level. In order to identify the set of strategies to be activated so that make positive impacts on all the nodes of the network this paper proposes an optimisation model of the network performance. In this way, the model allows to identify the set of strategies that together have positive influences on the achievement of all the objectives defined by the networked nodes. To address the raised problem, the authors adopt the system dynamics methodology.

When the strategies are formulated without considering the objectives of other enterprises and the influence they perform, this leads to a non-collaborative behavior and at the end the partnership failure. Therefore, supporting solutions are needed to identify the strategies whose activation promotes the enhancement of the partners' objectives belonging to a collaborative network.

3 System Dynamics method as a base to identify compatible strategies

This section is developed in order to give the reader a better insight of the method used to model the strategies alignment process. When talking about system dynamics it is essential to reference the work developed by Forrester (1961). Forrester is the precursor of system dynamics, through the development of Industrial Dynamics, providing a methodology for dynamics models simulation. System dynamics enables to understand the structure and dynamics of complex systems, such as the collaborative networks systems, building formal computer simulations of these complex systems for designing more effective policies (Campuzano and Mula, 2011). According to Campuzano et al. (2010) the purpose of system dynamics is to examine the interaction between various functions within a system, in order to facilitate the understanding of it and improve the interaction of the system components.

This paper is focused on simulating the network as a system to look for the influences appearing between the strategies formulated and the objectives achievement. Considering that the objectives are measured through key performance indicators, the use of system dynamics enables to model the extent into which the KPIs defined to measure the objectives are influenced by the activation of a particular strategy. System dynamics allows modelling the strategies alignment process and understanding the structural reasons that cause an optimal behaviour of the system in terms of activating the most suitable strategies in each enterprise belonging to the network. Thus, a networked partner can identify which strategies has to activate, in order to simultaneously benefit the achievement their own objectives and the objectives defined by other enterprises. As a result, the set of aligned strategies identified will favour the improvement of the network performance. The software used to model the strategies alignment process is *AnyLogic* (Anylogic, 2014). This software includes the system dynamics simulation and offers an optimisation tool to maximise the global network KPI through identifying the aligned strategies.

4 Compatible Strategies Identification

In order to determine what strategies are compatible, amongst all the strategies formulated within the network, in this section it is developed a model considering the theoretic body of knowledge of system dynamics. The main aim is to identify those strategies that being activated are compatible enough to positively influence the objectives defined by the other partners, maintaining their measurement indicators or even improving them, optimizing the network global performance. In the following subsections the variables used in the model are described (section 4.1). The model itself to identify the compatible strategies is developed in section 4.2. Finally, a numerical example is provided in order to show the model's applicability (section 4.3).

4.1 Definition of the model variables

In this sub-section the variables used in the model (further developed in section 4.2) are described. The definition of the variables is subject to the following assumptions:

- When modelling the network, it must be considered that each enterprise defines a set of objectives, and carries out a set of strategies to achieve these objectives.
- The objectives are measured through key performance indicators in order to quantify the extent into which are achieved.
- The KPIs are used to measure the influence that an objective experiences when a particular strategy is activated.

First of all the indices of the model are defined (Table 1).

[Table 1. To appear here]

The network (N_n) consist of i enterprises (e_i). The enterprise is the entity to be modelled (e_i). Each enterprise defines a set of objectives o_{ix}.

Due to the model, hereafter developed, is based on the system dynamics method, the classification of variables that the system dynamics makes is applied in the definition of the model variables. Three are the type of variables made in system dynamics (Campuzano and Mula, 2011): (i) stock variables, objects of the model that define the its state, (ii) flow variables, objects of the model that have an influence on the stock variables levels and (iii) auxiliary variables, objects defined in the model that influence on the performance of flows variables. Therefore, the variables defining the model to identify the compatible strategies are arranged according to the classification criteria proposed by the system dynamic method.

Stock Variables

- Budget, b_i – is the budget of the enterprise e_i to carry out the strategies s_{is}
- Key Performance Indicator, kpi_{ixk} – is the KPI defined to measure the objective o_{ix} defined in the enterprise e_i.
- Increase of the kpi_{ixk} when one unit of strategy sis is activated, ∇kpi_{ixk}^{is} – it represents a quantitative number that measures the influence of the strategy s_{is} formulated in enterprise e_i over the kpi_{ixk} defined in enterprise e_i to measure the objective o_{ix}

Flow Variable

- The total influence that the strategy s_{is} has over the kpi_{ixk}, $inf\_s_{is}\_kpi_{ixk}$ - according to the definition of s_{is} (number of units of strategy) it represents the formula of the influence that a specific number of units of strategies have over the KPI according to the variable ∇kpi_{ixk}^{is} the $inf\_s_{is}\_kpi_{ixk}$ variable is computed through $inf\_s_{is}\_kpi_{ixk} = \nabla kpi_{ixk}^{is} \times s_{is}$. The influence variable can be positive, represented by a positive number and implying an increase on the KPI, or on the contrary, it can be negative.

Auxiliary Variables

- Strategy, s_{is} – number of units of strategy s_{is} to be activated, defined in enterprise e_i (see figure 2)
- Cost, c_s_{is} – cost measured in monetary units of activating one unit of strategy s_{is} defined in enterprise e_i
- Monetary units invested, s_{is}_mu – monetary units invested in strategy s_{is} defined in enterprise e_i. It is computed through $s_{is}\_mu = s_{is} \times c\_s_{is}$
- Global key performance indicator, $kpiGlobal$ – is the result of the sum of all the kpi_{ixk}

[Figure 2. To appear here]

In the example of figure 2 it can be seen that one strategy can acquire two states: non-active or active. If the strategy has the active state, then the model identifies the number of units of strategies. The maximum number of strategies to be activated will be that in which the monetary units needed to activate it (s_{is}_mu) do not exceed the enterprises budget.

4.2 Model formulation

Based on the variables defined, a simulation model, using system dynamics, is developed to deal with the identification of compatible strategies. The proposed model aims to identify the set of strategies that increase the KPIs values. In general the model identifies the strategies that enable to increase the objectives within each enterprise and thus obtain an improved network performance.
According to the variables definition, each enterprise has associated a budget (b_i) to spend on the activation of strategies. Depending on the cost for activating one unit of strategy

(c_s_{is}) the budget (b_i) will decrease in a lesser or lager extent. The higher budget, the more strategies can be activated and the more strategies activated, the less quantity of monetary units remain in the budget (equations 1 and 2).

$$b_i = b_i - \sum_s s_{is}\_mu \tag{1}$$

$$s_{is_{mu}} = s_{is} \times c\_s_{is} \tag{2}$$

The $inf\_s_{is}\_kpi_{ixk}$ variable identifies how the activation of a strategy s_{is} influences in the kpi_{ixk}. On the one hand, the KPI can be increased or decreased by the activation of a strategy defined in the same enterprise and this will positively or negatively affect the enterprise's objectives (equation 3). On the other hand the KPI can be increased or decreased by the activation of a strategy defined in another enterprise belonging to the network (equation 4) (Andres and Poler, 2014a).

$$\inf\_s_{is}\_kpi_{ikx} = s_{is} \times kpi_{ixk}^{is} \tag{3}$$

$$\inf\_s_{js}\_kpi_{ikx} = s_{js} \times kpi_{ixk}^{js} \tag{4}$$

The overall influence over a kpi_{ixk} is defined by the equation 5:

$$\frac{d\ (kpi_{ixk})}{dt} = \sum_i \inf\_s_{is}\_kpi_{ikx} + \sum_j \inf\_s_{js}\_kpi_{ikx} \qquad \forall\ i,j\ \in e\ /\ i \neq j \tag{5}$$

The auxiliary variable s_{is} is the *decision variable* that identifies the number of strategy units to be activated in order to maximise the performance of the global network. The auxiliary variable *kpiGlobal* is the variable to be *maximised* in order to obtain the optimal solution as regards the unit of strategies (s_{is}) to be activated (equation 6).

$$max. \quad kpiGlobal = \sum_i kpi_{ixk} \tag{6}$$

Modelling the enterprises strategies and the objectives through the system dynamics allows determining which strategies promote higher values of KPIs. The model indeed, identifies those strategies that should be activated and those that should remain inactive in order to stabilise the network system and do not generate losses. The model has a single decision variable that indicates how many units of strategy s_{is} have to be activated taking into account (i) the influence of the strategies over the enterprises' KPIs ($inf\_s_{is}\_kpi_{ixk}$), (ii) the strategies activation costs (c_s_{is} and s_{is}_mu) and (iii) the capacity constraint defined by the budget in each enterprise (b_i), represented by equation 7:

$$\sum_s s_{is}\_mu \leq b_i \tag{7}$$

In the developed model, when a strategy is activated, the KPIs immediately increase (or decrease); therefore the model is simulated in the steady state. This first proposal of the model does not consider transient state. The simulation time step is one unit of time, in this simulation horizon the decision of how many strategies units are to be activated is made, obtaining maximum levels of network performance.

4.3 Numerical Example

A numerical example is developed hereafter in order to implement the defined model. A network of two enterprises is modelled (figure 3). The variables used in the example are described next:

- Network, N consists of two enterprises: e_1, e_2
- Each enterprise defines one key performance indicator: $e_1 = kpi_{111}$ and $e_2 = kpi_{211}$
- The KPIs are defined in order to measure the objectives achievement: $e_1 = o_{11}$ and $e_2 = o_{21}$
- Each enterprise defines two strategies that allows them to achieve the raised objectives: $e_1 = s_{11}, s_{12}$ and $e_2 = s_{21}, s_{22}$
- The strategies have associated a cost: $e_1 = c\_s_{11}, c\_s_{12}$ and $e_2 = c\_s_{21}, c\_s_{22}$.
- Each enterprise has a budget to activate the strategies: $e_1 = b_1$ and $e_2 = b_2$

The KPI increase, ∇KPI_{ixk}^{is} ($inf\_s_{is}\_kpi_{ixk}$) gives an insight on how the associated objective is influenced by the activation of a particular strategy

- The enterprise e_1 *has* defined the kpi_{111} and identifies:
  - the influences that the strategies defined in the same enterprise have over the kpi_{111}: ∇kpi_{111}^{11} ($inf\_s_{11}\_kpi_{111}$) and ∇kpi_{111}^{12} ($inf\_s_{12}\_kpi_{111}$)
  - the influences that the strategies defined in the other enterprise e_2 have over the kpi_{111}: ∇kpi_{111}^{21} ($inf\_s_{21}\_kpi_{111}$) and ∇kpi_{111}^{22} ($inf\_s_{22}\_kpi_{111}$)
- The enterprise e_2 *has* defined the kpi_{211} and identifies:
  - the influences that the strategies defined in the same enterprise have over the kpi_{211}: ∇kpi_{211}^{21} ($inf\_s_{21}\_kpi_{211}$) and ∇kpi_{211}^{22} ($inf\_s_{22}\_kpi_{211}$)
  - the influences that the strategies defined in the other enterprise e_1 have over the kpi_{211}: ∇kpi_{211}^{11} ($inf\_s_{11}\_kpi_{211}$) and ∇kpi_{211}^{12} ($inf\_s_{12}\_kpi_{211}$)

The proposed model determines the number of strategy units to be activated in each strategy, so that benefit both the enterprise that raises the strategy and the rest of the enterprises that belong to the network. The data regarding the variables needed to feed the model is depicted in Table 2.

[Table 2. To appear here]

System dynamics uses the causal loop diagram and the flow diagram. According to the variables and de mathematical model, in which the variables relationships are expressed, both diagrams are depicted. The causal loop diagram (figure 3) represents, through arrows, the relationships among the variables defined in the model. Each arrow is accompanied by a positive (+) or negative (–) symbol. The + symbol represents an influence on the same direction of one variable on another. The – symbol represents a change in the opposite direction (an increase on the original element produces an decrease in the destination element) (Campuzano and Mula, 2011).

[Figure 3. To appear here]

The flow chart allows translating the information from the causal loop diagram into a software tool in order to model the behaviour of the strategies and KPIs to identify those strategies that their activation implies to obtain maximized levels of performance within the collaborative network. The software tool used is *AnyLogic®* (Anylogic, 2014), the flow chart is reproduced in figure 4. This software allows translating the information depicted in the causal loop diagram into a terminology that enables to write the variables relations (Figure 4).

[Figure 4. To appear here]

The optimiser in *AnyLogic* runs the simulation model. The optimiser maximises the *KPI_GLOBAL*, according to the capacity constraint (equation 7), through modifying the parameters represented by the strategies s_{11}, s_{12} and s_{21}, s_{22} (figure 5). Then the optimiser runs the model multiple times and searches in the parameters space those that maximise the solution. Each dot in the graph corresponds to a single simulation run (Figure 6).

[Figure 5. To appear here]

[Figure 6. To appear here]

The optimisation experiment results conclude that enterprise e_1 should activate *16 units of strategy* s_{12} and enterprise e_2 should activate *37 units of strategy* s_{22} in order to obtain a maximised performance (38.684 units). Whereas strategies s_{11} (e_1) and s_{21} (e_2) should remain inactive.

The developed model is in the first stages, and although it has been applied in a simple numerical example, it could be applied in a network of *i* enterprises with *s* strategies and *k* KPIs. The configuration of this model serves as a basis to calculate the parameters s_{is} that maximise *kpiGlobal*.
So far, the implementation of the model presents some drawbacks related with the data collection. In current heterogeneous networks is usually to find a situation in which enterprises are not willing to share data and it is well known the uncertainty that characterizes the network. The incomplete information that enterprises have when trying to quantify the influences between the strategies activation and the KPIs levels is an added limitation. In the light of this, the developed model should in further stages to contemplate the information constraints and provide a methodology to help enterprises in gathering the data required to feed the model.

In spite of the existence of these limitations, the developed model is considered a useful approach to identify those strategies that if activated maximize the network performance.

5 Conclusions and Future research lines

The problem of identifying strategies to be activated in order to obtain positive and increased benefits in the performance measurement is solved in this paper through the mathematical model developed. The model outputs allows enterprises to identify those strategies that are coherent and compatible. The model has its background on the system dynamics method, that enables to model the impact that the activation of the strategies have in the KPIs of one enterprise at the same time that is computed the impact on other enterprises in the network when the first one actives one or more strategies. The simplicity of the model makes it to be very useful for enterprises implementation.

Future considerations are led to improve the proposed model through:

- Considering that there is a feedback from the gains obtained in each enterprise KPI towards the initial budget owned by each enterprise.
- Applying a delay. Instead of having an instantaneous response in the KPI levels when strategy is activated, considering a delay on the KPI influences could provide more accurate solutions. So that, the time variable is to be introduced in the model.
- Once introduced the time variable not only decide what strategies activate but also decide in when activate them.
- Design a methodology to allow enterprises to gather the input data to introduce in the model such as the variables that are represented by ∇kpi_{ixk}^{is}
- Apply the model in a real collaborative network

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Author

Tables

Table 1 Indices

Indices	
n	number of networks
i	number of enterprises belonging to the network
x	number of objectives defined by one enterprise
s	number of strategies defined by one enterprise
k	number of KPIs defined to measure one objective

Table 2 Data of the Numerical Example

				e_1 (b_1 = 100)		e_1 (b_2 = 150)	
cost c_s_{is}		s_{is}	s_{is}_mu	o_{11} (kpi_{111})		o_{21} (kpi_{211})	
c_s_{11}	5	s_{11} = ?	s_{11} × c_s_{11}	∇kpi_{111}^{11}	1	∇kpi_{211}^{11}	-0.3
c_s_{21}	6	s_{21} = ?	s_{21}× c_s_{21}	∇kpi_{111}^{12}	0.5	∇kpi_{211}^{12}	0.7
c_s_{21}	10	s_{21} = ?	s_{21}× c_s_{21}	∇kpi_{111}^{21}	0.5	∇kpi_{211}^{21}	0.5
c_s_{22}	4	s_{22} = ?	s_{22}× c_s_{22}	∇kpi_{111}^{22}	-0.5	∇kpi_{211}^{22}	1

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Figures

Figure 1. Objectives performance influenced by the strategies activation

Figure 2. Example to describe the units of strategy

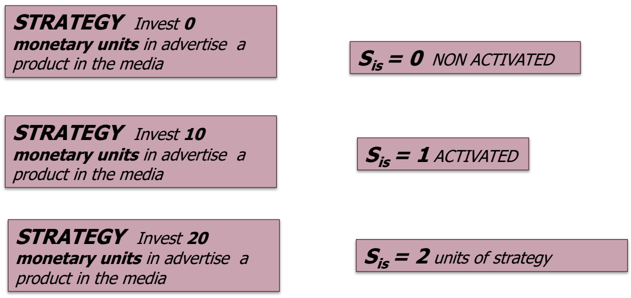

Figure 3. Numerical Example: Causal diagram

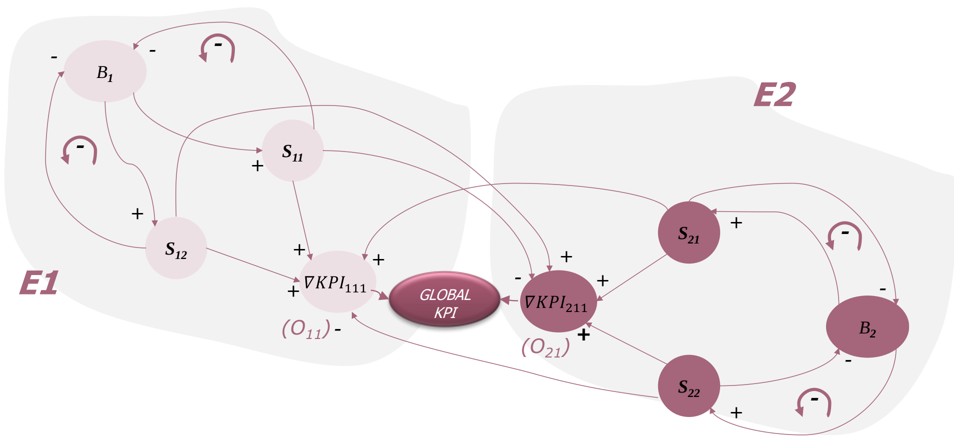

Figure 4. Flow chart diagram: Identifying the strategies to activate in *AnyLogic* software.

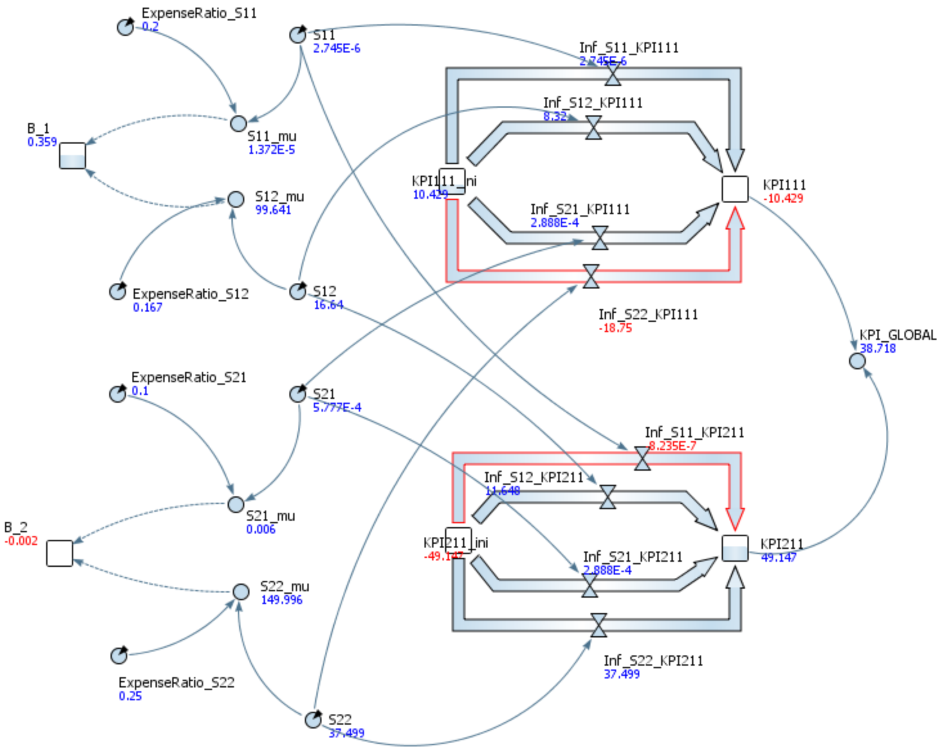

Figure 5. Optimisation Experiment: Objective, Parameters and Restriction.

Objective: ○ minimize ◉ maximize

root.KPI_GLOBAL

Parameters:

Parameter	Type	Value			
		Min	Max	Step	Suggested
S11	continuous	0	20		10
S12	continuous	0	17		8
S21	continuous	0	15		7
S22	continuous	0	38		18
ExpenseRatio_S11	fixed	0.2			
ExpenseRatio_S12	fixed	0.1667			
ExpenseRatio_S21	fixed	0.1			
ExpenseRatio_S22	fixed	0.25			

Requirements (are tested after a simulation run to determine whether the solution is feasible):

Enabled	Expression	Type	Bound
☑	root.B_1	>=	0.0
☑	root.B_2	>=	0.0

Figure 6. Optimisation Experiment: Results

	Current	Best
Iteration:	2,002	1,968
Objective: ⬆	38.684	38.684
Parameters		
S11	0.01	0.01
S12	16.66	16.66
S21	0.18	0.18
S22	37.01	37.01
ExpenseRatio_S11	0.2	0.2
ExpenseRatio_S12	0.167	0.167
ExpenseRatio_S21	0.1	0.1
ExpenseRatio_S22	0.25	0.25
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