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A Model for Systemic Control

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Abstract. Where should one begin with a design for the self-control of social systems? That is the question addressed by this paper. The traditional concepts of control rest on the feedback loop; control is essential to the attainment of goals. However, the simple feedback loop is insufficient for the modeling of a control system for an organization or other social system. For those systems, which search for multiple goals, it is necessary to design multilevel control systems incorporating the notion of pre-control. This eminently anticipatory function has hardly been considered by past research. Pre-control as understood here is a higher-order control that takes place between different logical levels of a control system. The Model of Systemic Control (MSC), a framework for multilevel control with pre-control relationships, is expounded and illustrated by means of a System Dynamics model.

Keywords: Model of Systemic Control, pre-control, System Dynamics, multilevel control

PACS: 89.65.-s, 89.65.Gh, 89.75.-k

1. INTRODUCTION

In contexts of high complexity, the approach to control in social systems has increasingly become one of self-control. Hierarchies become obsolete. Organizations are constituted by self-contained units which absorb complexity along the fronts on which they operate. Self-control is necessary to minimize delays and to enable competent action at the local levels.

This paper addresses the related questions of where a design for self-control should start and of how to conceive of self-control in order to be effective.

First, we elaborate on the notions of self-control as well as pre-control, and we introduce the Model of Systemic Control (MSC). Then, an implementation by means of the System Dynamics methodology is documented, including a number of simulations. Finally, the results are discussed, insights derived, and conclusions drawn.

2. ON MODES OF CONTROL

In this section, two distinctions are introduced. First, there is the distinction between self-control (also eigen-control, auto-control or internal control) and external control. The relevance of self-control has been emphasized at the outset; but even so, no organization can rely exclusively on self-control. The necessity of sub-units forming a coherent whole imposes a need for some degree of external control by which exceptions are taken care of and cohesion is fostered [1]. Therefore, in the real world organizations are subject to a mix of external control and self-control. External control and self-control are both necessary and complementary (Fig. 1).

The second distinction differentiates between control and pre-control. Control is the process by which a system regulates or steers itself or is steered and regulated in such a way that it achieves its goals. Here, regulation via feedback and foresighted steering based on feed-forward complement each other. The former is based on information about past performance, the latter on information about upcoming disturbances.

The power of control in this sense is limited, insofar as it cannot change the operations themselves. For this purpose, a higher-level type of control is necessary. We call it pre-control - the anticipative creation of preconditions at a higher logical level, preconditions which largely predetermine what can be achieved by the lower logical levels of the system under study.

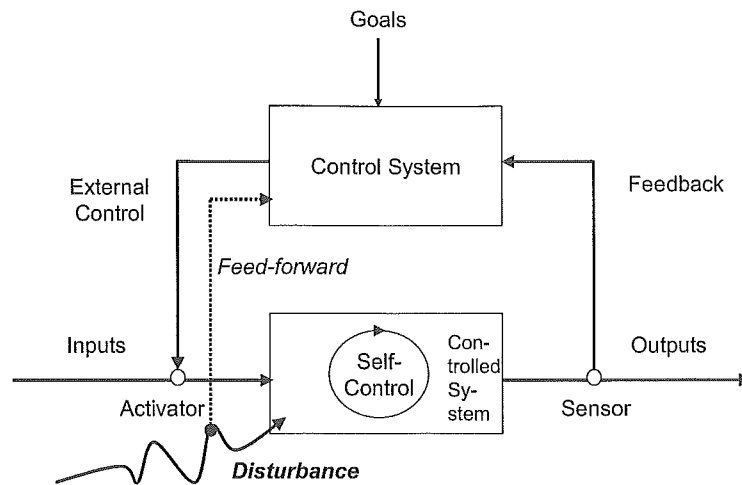


FIGURE 1. Control Process with external and self-control.

Figure 2 shows a pre-control sequence covering three levels. From top to bottom the pre-control parameters exert an influence on the respective lower levels, in the sense that they enable or inhibit what is possible at those lower levels, in terms of system behavior or performance. This will be illustrated with reference to an enterprise. The control variable u''' for example could be system structure or system culture, which determines y''' , the viability of the organization. Viability can be regulated only at level three. However, it exerts a pre-control influence on u'' , which could be market share or customer benefit. The regulated variable in this case is y'' , or value potential. Finally, value potential pre-controls u' - in this case revenue and cost, which are the determinants of y' or profit. The punctuated lines represent possible upward-directed feedbacks.

Pre-control manifests its consequences along the time axis, which will be introduced in the next step. At this point it should have become apparent that it is impossible to wield pre-control by means of the same variables by which control is exerted. The two kinds of variables are categorically and logically different.

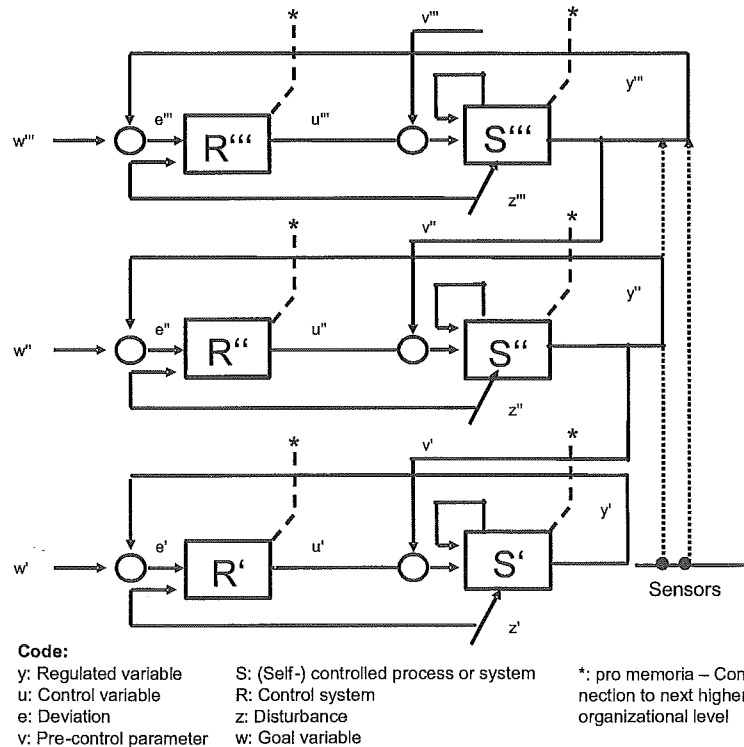


FIGURE 2. Pre-control sequence.

3. A FRAMEWORK FOR SYSTEMIC CONTROL

In this section a framework called *Model of Systemic Control (MSC)* will be presented (based on [2]). This is a highly abstract, general model for multilevel control. It capitalizes on the concept of pre-control, which has hardly been considered in past research (exceptions are [2, 3, 4]).

The MSC is based on the insight that one and the same system must govern itself by means of a set of control variables which belong to different logical levels, namely the levels of operative, strategic and normative management. This necessity implies possible (and probable) contradictions between these control variables.

As shown in Fig. 3, there are pre-control relationships between the three levels, just as already outlined with regard to Fig. 2. The general goal of the firm at the operative level is to create value, i.e. benefits for the stakeholders (particularly customers, personnel and owners). Specific control variables for achieving this are value for customer, economic value and social and ecological benefits.

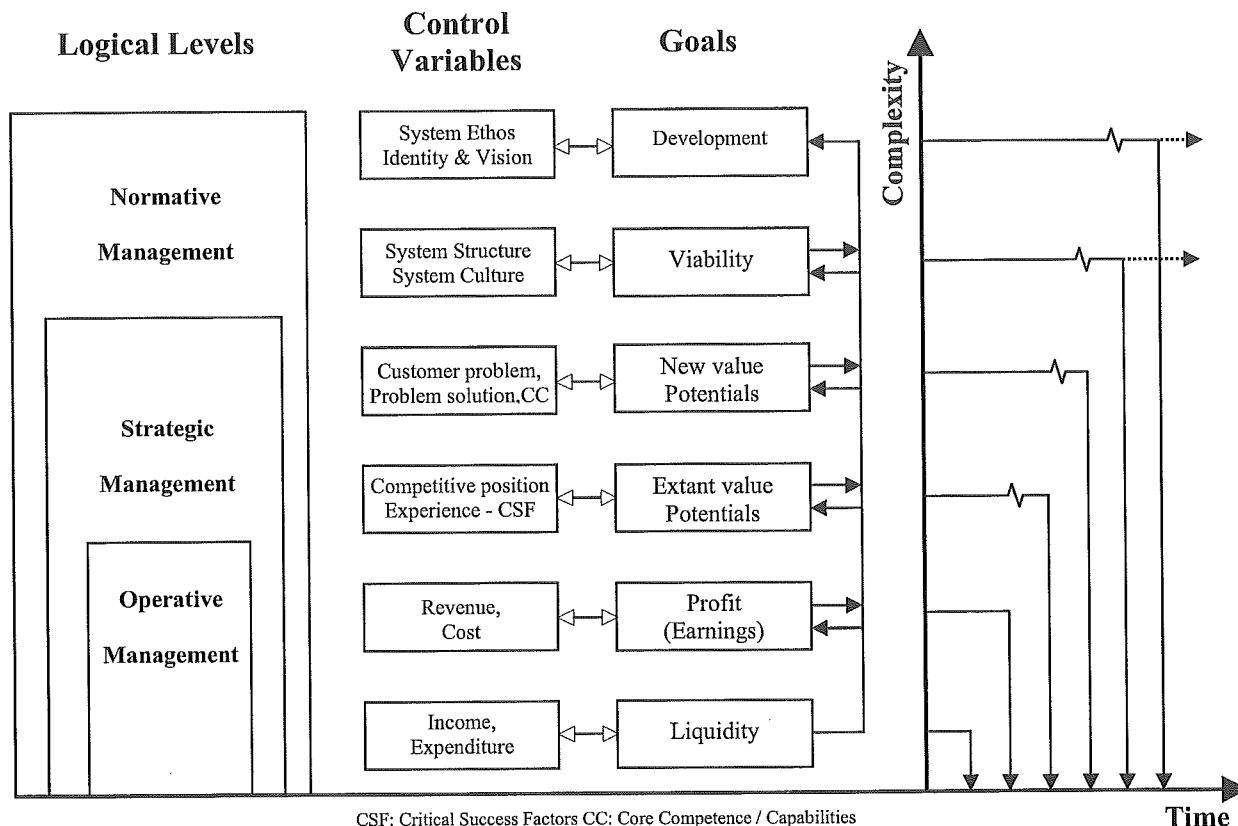


Figure 3. Model of Systemic Control

The traditional steering models of firms, for example, were almost exclusively orientated towards *profit* and *liquidity*. But profit behaves in an inherently short-term-mode, and its level is largely predetermined by parameters of another nature (just as liquidity is largely predetermined by profits). Similarly, a customer benefit derived from a product or service hinges on prerequisites which must be fully available in, and therefore built up well ahead of, the "moments of truth" [5], i.e. when production and delivery take place¹.

Good managers have always known that the attainment of operative goals is bound to preconditions that have to be created in advance. The values which a company can generate are largely predetermined by the value potentials created beforehand. Value potentials are defined as the set of all applicable business-specific prerequisites (e.g. in the form of resources, capabilities, core competencies) that must be fulfilled when value is to be provided (in

¹ For didactic reasons, Fig. 3 is simplified in that, at the operative level, it shows explicitly only the financial variables, not the values for customer, social and ecological benefits. These are visible elsewhere, in a more general but less concrete scheme [6].

extension of: [3]). These represent operational and calculable categories; their patterns of behavior can be foreseen and influenced (controlled). Value potentials must be controlled separately from value, on the basis of independent criteria.

Research on strategic management has clarified the nature of these criteria and shown, for instance, how to apprehend the critical success factors (such as market share, relative market share, quality/customer benefit, speed, flexibility etc.)² in a given business system [7]. This is knowledge about *extant value potentials*, and it is therefore of limited usefulness in turbulent environments. The management of *new value potentials* is about building core competences/capabilities and therefore includes changing established patterns, taking into account the dynamics of customer problems, problem solutions (i.e. products/services) and technological substitution, along the value chain or in the value-generating network, respectively. This involves a sustained long-term effort for innovation, and it often requires a redesign of the business system.

Due to the nature of pre-control, profit is not a strategic variable, and consequently not a strategic goal either. Rather, its appearance or absence is a result of good or bad strategies.

At the level of normative management, independent criteria for the assessment of the viability and development of organizations do exist. Viability, understood as the ability to maintain a separate existence [8:113], i.e. a distinct configuration which makes a system identifiable as such, can be assessed on the grounds of structural considerations which are not bound by the orientators of the strategic and operational levels. To date, the most advanced theory for assessing the viability of an organization in functional terms is the Viable System Model [8, 9, 10]. This model is an excellent conceptual device for diagnosing and enhancing the viability of an organization, independent of the steering criteria of the lower levels (strategic and operative).

As far as the *soft factors* of organization are concerned - referred to under the common denominator of *culture* - many descriptive models have been elaborated. Even though design here is subject to limitations, certain models for diagnosing and changing organizational cultures [e.g. 11] and for the design of learning organizations [e.g. 12] have been made available. The keywords *ethos of the system*, identity and vision are other "soft" aspects with which the normative management is concerned. They have been treated extensively in [6].

In this control system, the variables regulated at one level are the pre-control parameters for the next level down. The relevant time horizon increases from operational to normative management. At the same time, the factual horizon is also extended, as is the complexity which is to be coped with. The dotted arrow indicates that certain principles of normative management (e.g. ethical and aesthetic ones) are largely timeless.

The key duty of an integral or systemic management is to maintain the variables of all three levels under control simultaneously over time, despite the contradictions and trade-offs which will arise between the levels, and thereby to meet the different criteria of systemic effectiveness:

- at the operative level: efficiency, in terms such as quality, productivity and profitability;
- at the strategic level: effectiveness in terms of both competition and co-operation;
- at the normative level: legitimacy, i.e. the ability to fulfil the justified claims of the stakeholders.

In order to achieve such a delicate task a corporation will require considerably higher developed mental models than the established ones, and more complex control systems than the simple feedback systems traditionally used.

4. IMPLEMENTATION BY MEANS OF A SYSTEM DYNAMICS MODEL

The following simulation model was designed by means of the System Dynamics methodology³. It is an abstract and therefore simplified representation of an organizational control or management system. Its purpose is to reflect, in principle, which patterns of systemic behaviour evolve as a function of the multilevel aspects of pre-control in an organization.

We will divide this part into a walkthrough, where the model variables are explained, and into an explanatory part, where the logic of the model is compared to the MSC.

We will start our walkthrough of the model at the lowest level (Fig. 4). This is the level of liquidity (variable *cash*). In the model it is pre-controlled, as it is in reality, by the profit level, namely the inflows are connected to the revenues of the company while the outflows are a function of the costs. Another influencing factor for both flows is the payment schedule. Here, the payment schedule is held fixed at a one-month delay, meaning that both the inflows and outflows follow the respective revenues and costs one month later.

² Critical success factors can vary among different businesses.

³ System Dynamics is a methodology for the modeling and simulation of complex dynamical systems. It was invented by Professor Jay Forrester at M.I.T. [13]. It has been applied to multiple domains and aspects of social (and other kinds of) systems [14].

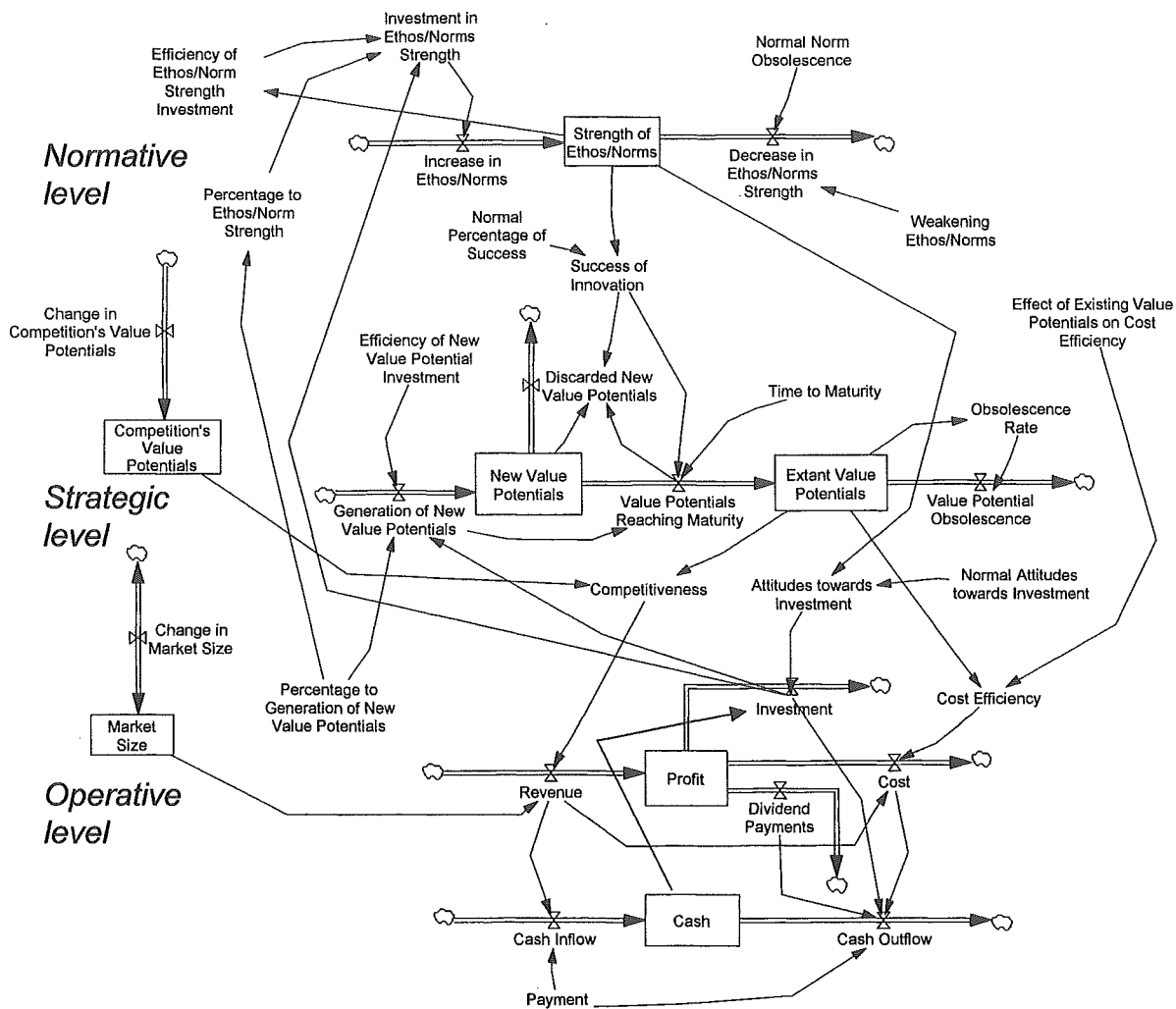


FIGURE 4. System Dynamics Model based on the MSC.

The next-higher variable regulated by operative management, profit, is directly pre-controlled from the strategic level, as well as registering some pre-control stemming from the normative level. Revenues are being modeled as a function of market size and competitiveness. We determine the competitiveness ratio as a function of our and the competition's extant value potentials; market size grows slowly in the default scenario (see next section). Costs, on the other hand, are affected by cost efficiency as well as by the revenue. In this model, non-trading – namely generating zero revenue – lies outside of the acceptable range of behavior, as that would present non-realistic values for costs. The cost efficiency is pre-controlled by our extant value potentials, which can be due either to a cost advantage or to differentiation.

We modeled investment in innovation separately from cost. Profit, which remains after the costs have been subtracted, can either be invested for further innovation or kept (improving our liquidity). A third option, namely paying it out as dividends, is also included in the model, but as external financing lies outside its boundaries, dividend payments are not of importance here. Investment depends also on the attitudes we have towards investment, and so these are pre-controlled from the highest, normative level.

Moving to the strategic level, new and extant value potentials are linked with the help of an aging chain, where new value potentials are generated as a function of investment, and then mature into extant value potentials with first a time delay, and second a loss of the ones not deemed useful. There is an obsolescence rate, meaning that value potentials lose their value with time. So in order to keep the extant value potentials constant or to increase their number, investment in generating new ones is necessary, as otherwise a slow decline of the business occurs. The

generation of value potentials is influenced by the amount of the investment that comes from the funds generated at the operative level, as well as by the normative level, which has an effect on innovation success. As the amount of investment in the model is pre-controlled by the attitudes towards investment - a value influenced directly by the normative level as well - a consistent picture of pre-control emerges. Please note that it also includes feedbacks between the different logical levels. In this simple SD model we have compressed the normative level into one stock, condensing the development and viability sub-factors of the complete MSC. The strength of ethos/norms can increase as a result of an investment into that sector, and fall as a result of either weakening or obsolescence. While certain norms are timeless for all practical intents and purposes, some do become obsolete with changes in the environment. Equally, a weakening of ethos from inside is conceivable. The erosion of ethos needs to be countered by means of continuous investment into ethos/norm strength building.

This concludes the walkthrough and brings us to the part where the operation and logic of the model are explained - namely the reasons for the various links and their significance in the context of the MSC framework.

The central stock of the normative level, namely the strength of ethos/norms, encompasses aspects such as identity, vision, system ethos, and underlying organizational fundamentals as well as system culture. We decided to focus on one stock variable so as to avoid the problems of quantifying the minute relationships between the various aspects involved, as opposed to the model of a real life example where quantification would be more straightforward.

There are two influences on lower levels which emanate from the normative level, the first on the percentage of innovation success, and another on the proportion of leftover cash invested into innovation. The logic behind the first is that a company with a strong ethos and a strong cohesion, shared understanding etc. is less likely to suffer innovation failures due to internal sabotage, misunderstanding between the various parties involved and similar negative outcomes. However strong the ethos might be, there still remains a residual risk, and therefore the percentage of innovation success can never reach 100%.

The second influence or link is to the percentage of spare funds reinvested in innovation. The idea behind this link is that a company with strength at the normative level takes a long-term perspective and is more successful at defending both the enhancement of future value potentials as well as the upkeep of corporate-ethos strength. In the case of strong ethos, a significant percentage of spare cash will be invested into the future, the only exception being if a liquidity crisis looms. In such a case operative costs would assume priority, as the primary objective here is short-term - that is, making sure the business does not default.

At the strategic level, value potentials can belong to either the new or extant categories. These make up an aging chain, where new value potentials mature into existing ones. Extant value potentials then determine both the competitiveness and cost efficiency of the business. This whole aging chain is pre-controlled by the normative level, as described above. New value potentials need a given amount of time to reach maturity, and not all of them do, as the result either of innovation failure or of changed environmental circumstances. The obsolescence of extant value potentials is first of all dependent on an obsolescence rate (related to the type of value potential) as well as the size of value potentials. The latter link signifies the fact that the larger value potentials are, the higher the fraction that becomes obsolete over a period of time. Again, there are some which cannot be copied or do not become obsolete. The obsolescence factor also allows us to test scenarios in which the current business environment changes dramatically.

The stock variables⁴ of the strategic level have two effects on the operative level, namely one via competitiveness, the other one via cost efficiency. Competitiveness pitches our company against the competition to determine whether we are providing better-suited solutions to the customer's problems than the competition does; this determines the firm's market share. It depends on the extant value potentials in relation to the competitors', and can come in the form either of differentiation or cost leadership. Competitiveness, then, has an effect on the revenues generated by the company.

Cost efficiency, on the other hand, affects the costs. It is a factor determining how high the costs are as a percentage of revenues. The higher the amount of value potentials, the lower the cost level, as a function of two mechanisms: either the firm produces a differentiated product, meaning that it can demand a price premium at a constant product cost, or the production cost - as a function of the experience curve - is lower than that of the competition, where again the company's profits grow, because at a constant price the production cost is lower.

The operative variables then feed back to both the normative and the strategic ones through the investment into those two levels. In the case where profits are hoarded or distributed as dividends, i.e., not reinvested, the short-term result is going to improve but the company will suffer in the long run, as both the strength of ethos as well as the size of extant value potentials will be impaired. If too much is invested, on the other hand, this could leave the company

⁴ Stock variables are graphically represented as rectangles (see Fig. 4).

with a weak cash position. The various possibilities will be examined in some tested scenarios, as described in Part 5.

5. SIMULATION RESULTS

We tested several scenarios with the model, starting with a base scenario (serving also as a default scenario). We continued testing for the effects of not investing into ethos/norm strength, then determining an optimal proportion to be invested at the various levels and finally examining the effects of certain changes in the market environment⁵. The scenarios were as follows (see Figs. 5 to 8):

5.1. Base Case (denoted as #1 in Figs. 5ff.)

In the base case the setting is to invest 10% of the innovation money into the strength of ethos/norms and 90% into new value potentials. The strength of ethos/norms slowly grows from the start, while both the extant and new value potentials need significant time to really take off in growth, after which they start displaying goal-seeking behavior, with a slight growth still apparent at the end of the simulation. Profit and cash levels grow correspondingly.

5.2. Investment Into new Value Potentials (denoted as #2 in Figs. 5ff.)

This scenario envisages the situation in which the company focuses on investment into new value potentials only, to the detriment of investment in ethos/norm strength. Not surprisingly, the results take a significant turn for the worse over the whole period, with a decline in extant and new value potentials even at the points where significant growth was present in the base case. This clearly confirms the notion that normative management is very important, at least in the long run.

5.3. Optimization of Investments (denoted as #3 in Figs. 5ff.)

The next scenario uses the inbuilt VensimTM optimizer, with the goal of determining the optimal amount to invest into the strategic and normative levels. The value returned was even higher than the initial 10% we set for the share of total investments allocated to the normative level, namely 18.61% for normative, with 81.39% going to the strategic level. A note of caution is necessary, though, in interpreting the results. As the model is a general representation of a theory, the numbers cannot be taken at face value, as they would depend on the specific company situation. The optimization result does show, however, that a significantly higher percentage invested into the normative level brings marked improvement in the results overall. In the later stages of the simulation the results of the base case are better as far as the strategic and operative levels go, but due to the early head-start of the optimization run still a better result overall is produced.

5.4. Tougher Competition (denoted as #4 and 5 in Figs. 5ff.)

Next to come are the scenarios which feature tougher competition. In the previous scenarios (#1,2,3) the competitive pressure kept on increasing for some time until a sufficient amount of extant value potentials was reached, therewith rectifying the competitive position of the company. In scenarios #4 and 5, however, the competition has a growth rate twice as fast as in the base case scenario. With base-case settings for everything else, the results are abhorrently bad. In the strategic level the results are at a level with (but still marginally above) those from the no-ethos/norm-strength investment run, while at the operative level they are worse than in even that run. The optimization run in this scenario shows that it does not need to come out this way. The optimal result, namely 78.46% of the investments going to the strategic level and 21.54 to the normative level, shows that in this case the normative level gains in importance, even though normal management wisdom would suggest that in such a crisis investing into short-term actions is the route to take. The results are not quite as good as in the cases with normal competition (#1 and 3), as is to be expected, but they still reach relatively high levels overall.

⁵ The time horizon chosen is very large - 100 years. This enables a) recognizing long-term consequences of present activities and b) verifying if the model generates results that make sense.

5.5. Declining Market (denoted as #6 and 7 in Figs. 5ff.)

Finally, the scenarios with negative market growth totally reversed the trend, simulating a decline of equal proportion to the base-case growth. This produced results which were worst of all at the operative level and slightly better than the ones without investment in ethos (#2) at the beginning but worse at the end, in terms of the strategic level. An optimization run (#7) confirmed the results of the previous scenarios tested, namely it returned an even lower proportion of the investments devoted to the strategic level and an even higher one to the normative level (69.17% versus 30.83%), improving the results for value potentials substantially and for cash as well as profits to a lesser extent.

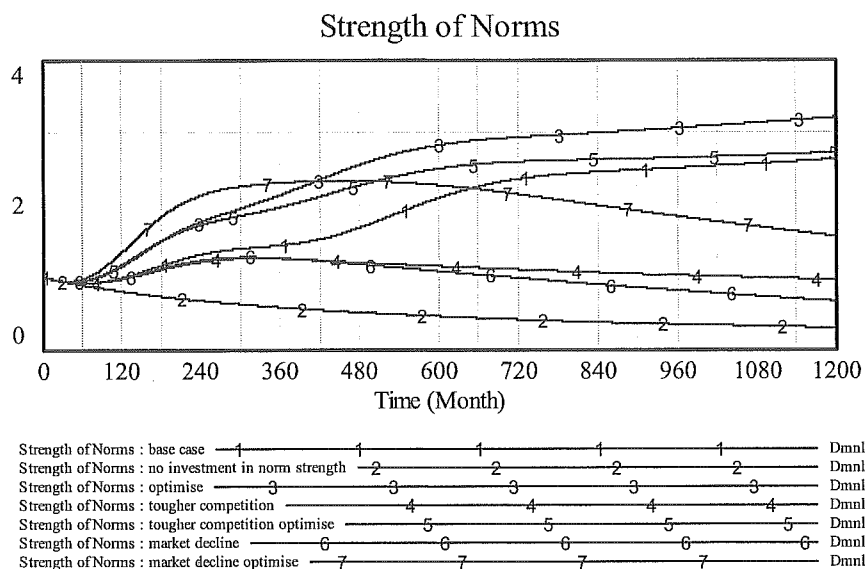


FIGURE 5. Strength of Ethos/Norms - Results for the different scenarios.

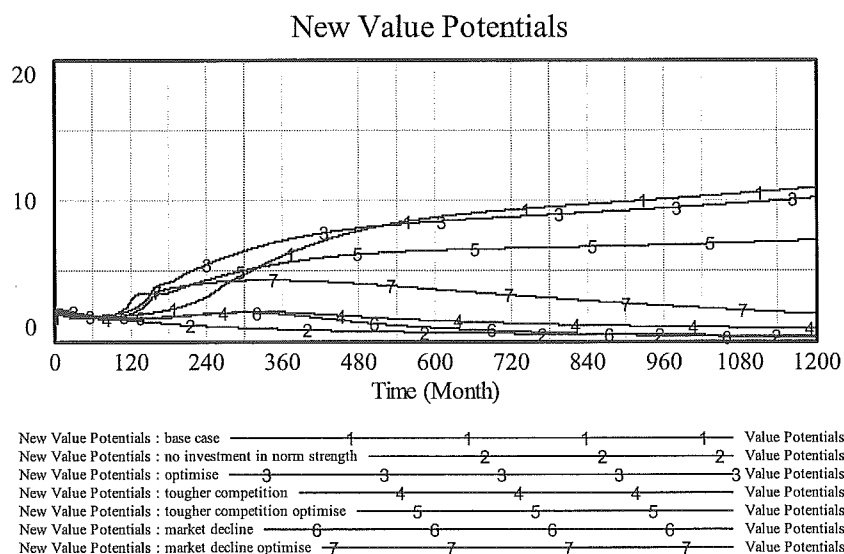


FIGURE 6. New Value Potentials - Results for the different scenarios.

Existing Value Potentials

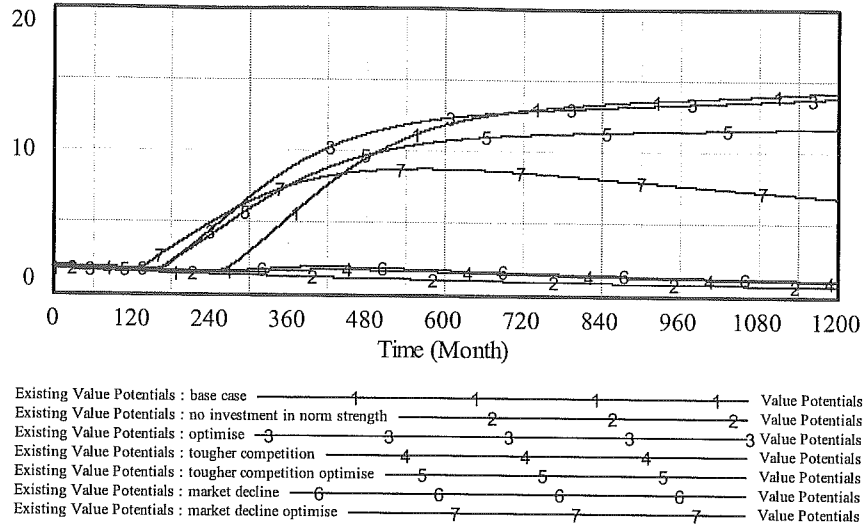


FIGURE 7. Extant Value Potentials - Results for the different scenarios.

Profit

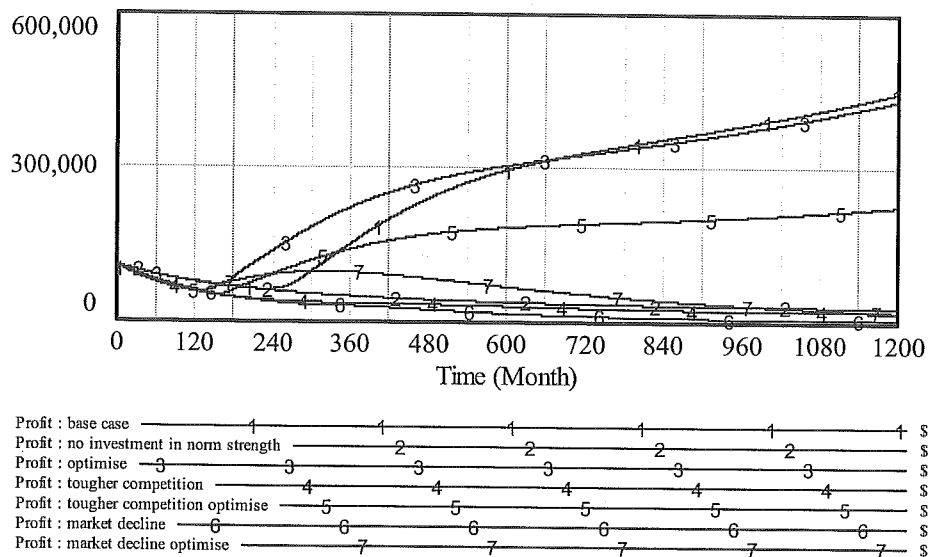


FIGURE 8. Profit - Results for the different scenarios.

6. DISCUSSION: CONTRIBUTION TO ANTICIPATORY SYSTEMS RESEARCH

Holmberg underlined the anticipatory characteristics of the MSC in its linking of anticipatory theory with system concepts [15]. In short, the MSC is understood as "multimodal anticipation" (ibidem, p. 80), given that models of higher logical levels pre-control performance at lower logical levels (see Fig. 3); this systemic characteristic is the anticipatory character of the MSC.

A particular point must be discussed: although retardation effects have been formally included in our model, anticipation - taken as future states of the model being used to compute present states - is not explicitly formulated, an issue already discussed in the work of Asproth, Holmberg and Hakansson [16] regarding system dynamics

models. Yet at the same time our model includes feed-forward control based on information about upcoming disturbances (see punctuated line in Figure 1). For instance, an anticipated increase in the value potentials of the competition results in a reduction of the firm's competitiveness (Fig. 4). The pertinent signal should induce compensatory measures. These additional aspects could easily be incorporated in the model.

In our model we present the impact of models representing interconnected different logical levels of the control system, with the upper levels carrying out anticipation via pre-control over a long-term horizon.

Dubois and Holmberg [17] already developed a computer simulation model based on the MSC making use of differential delayed-advanced difference equations [see 18]. In this work, in order to advance a further step investigating the MSC, we took a slightly different path using the system dynamics approach and maintaining the CAST⁶ spirit regarding the use of computer simulation. In particular we included specific business concepts such as cash, profit, market size, value potentials, and so on, with the aim of advancing the analysis of the anticipatory capabilities of the MSC, as proposed by Dubois and Holmberg [17]. It has been shown how investment in the upper levels of the management system creates the preconditions for better performance at lower, short-term oriented levels; this manifests the impact of normative management. The results at the operative level become far better in the long run given the pre-control exercised from the higher level. Following the suggestions of Holmberg [15], the approach presented here may enrich and complement the view of Anticipatory Modelling and Computing as a Systems Science.

7. INSIGHTS AND CONCLUSIONS

By means of the MSC and its implementation in a System Dynamics model, we have illustrated the phenomenon of pre-control as a proactive form of anticipation. Pre-control is more focused on what *could* happen (potentiality) than on what is happening or will happen (actuality). It anticipates a whole range of potential impacts from parameter changes and enables one to counteract them with a robust strategy.

Given the structure of the model, the behaviour patterns simulated convey a number of insights, namely:

- Achieving future benefits requires sacrifices in the present. Consequently, there is always a trade-off between future and present gains. These trade-offs can only be made tangible by means of simulations.
- Understanding the nature of pre-control (as opposed to conventional control) is a powerful form of anticipation. It enables the design of robust responses to anticipated changes and restrictions.
- The scope and strength of those responses increases from bottom to top (Figs. 2 and 3), i.e. from operative to strategic, and finally normative management.
- Equally, the sustainability of the controls grows from bottom to top.
- As a consequence, the priorities are made clear, as resources for responses and the development of the organization are allocated to the different levels.

The initial question of the paper was where a design for self-control should start. The answer is that the primary initial focal point is not the structure of the organization. The design should start in the mind of the observer, who must understand the nature of pre-control in the first place. Today, actors at all levels of organizations are equipped with increasing autonomy and discretion in order to be able to cope with complexity. To be effective, they need to master the multilevel nature of control, and this mastery requires conceptual understanding more than anything else. The present paper offers itself as a first blueprint for such understanding.

Finally, to put our message in practical terms: The model expounded here indicates that it is wrong to try running a firm on the basis of profit-maximization. We must not let the craze for profits and share prices delude us. Profit is not a strategic goal. It gives no clue about either the viability or the potential of a firm. It is only a short-term indicator. What we must do instead is look at the pre-control sequence which emanates from the normative level and which via the strategic level determines profit and liquidity. From taking such a vantage point, it becomes clear that both value potentials and the strengths at the normative level need to be built up by means of a sustained effort.

Such an integrative perspective will enable a manager to maintain simultaneous balance among the control variables at the different levels. This is the key to systemic management.

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⁶ CAST stands for *Computer-Aided Systems Theory* - a school of the Systems Approach focused on quantitative model building.

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