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Dynamics of Managerial Intervention in Complex Systems

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ABSTRACT

Research, as well as decades of working with managers from diverse cultures, nationalities, and industries, has exposed consistent counter productive patterns of behaviour in relation to decision making in complex systems. In this regard, managers appear to exhibit an unmistakeable tendency to "over intervene" in the systems (companies, organizations, communities, etc) for which they are responsible hence generating unnecessary fluctuations and instability in their organizations. Maani, et al (2004), and Sterman, et al (1989; 2000) have studied these phenomena in experimental and simulated environments respectively. Anecdotal evidence, as well as research results, highlights a number of mental models and assumptions commonly held by managers. These are outlined below:

1. Dramatic change should lead to dramatic (positive) results. Our research shows that often the opposite happens.
2. The more change initiatives (interventions), the better the results. Again our research shows that "over-intervention" is counter-productive.
3. Managers often ignore "soft" variables (eg, morale, stress, burnout, loyalty, etc) to the detriment of their organizations. Yet, "soft" variables are powerful predictors of long-term performance.
4. Managers are often oblivious to "systems delays". Lack of awareness/attention to delay undermines performance and inhibits system stability.
5. Organizations and managers often judge performance by short-term results. Experience shows that expectation of short-term results is unrealistic and misleading and can lead to counteracting outcomes as performance often declines before it improves.
6. Organizations and managers tend to use too many performance measures (ie, KPIs). As what gets measured impacts performance, excessive and misguided measures can lead to poor results and unexpected consequences.
7. Managers generally focus on "what to dos". It is not enough to know *what* needs to be done. *Order* and *timing* of actions are as important as the actions themselves.

The propositions and observations outlined above collectively form the research questions posed in this paper: "How do the style (extent) and frequency of change and the interpretation of feedback affect the outcomes of interventions in organizations?" In this research, realistic simulation models of organizations (Microworlds) are employed as proxy for complex systems. Research subjects comprise MBA and graduate business students and practicing managers. The paper deals with systems thinking theory and practice in complex decision-making and their implications for transforming managers and organizations to achieve sustainable success.

Key words: Systems Thinking, Complex Decision-Making, Dynamic Behaviour, Change Management

INTRODUCTION

In the past three decades, much research has explored the complexity of decision-making under the 'bounded rationality' of human mind. This includes studies by Simon (1957, 1979, 1987), Morecroft (1983, 1985), Senge (1990), and Sterman (1989, 2000). The latter three have related this dilemma to systems thinking theories. According to Richmond (1994), systems thinking is "the art and science of making reliable inferences about behavior by developing an increasingly deep understanding of underlying structure". By understanding problem situations with a systems perspective, a more holistic understanding can be achieved in terms of the causal relationship between decisions, interventions, and their expected results. Under bounded rationality, it is not realistic to expect that interventions will yield the expected (and only the expected) results. Further, decisions made with good intentions do not always result in the favourable outcomes anticipated by the decision maker.

Likewise, a substantial amount of research has been carried out in relation to the dynamics of decision making with a systems thinking perspective. This includes "Limits to Growth" (Meadows, 1972), "System Dynamics: Portraying Bounded Rationality" (Morecroft, 1983), "Beyond the Limits" (Meadows, 1992), and the "Improvement Paradox" (Keating et al., 1999). While these studies provide significant insight into the formulation and outcomes of decisions, the empirical work in the area of decision dynamics and interventions in complex systems remains elusive.

RESEARCH OBJECTIVES

The objective of this study is to explore the dynamics of "interventions" in complex systems. To our knowledge there are no serious research, e.g., in System Dynamics, which investigates the causes and consequences of over-*intervention*. This paper, as part of a broader research, aims to address the apparent gap in this filed.

In the context of this research, *intervention* is broadly defined as any action that changes the state of a system, and is further quantified by the number (Frequency) and the magnitude (Style) of change (intervention). The research will involve empirical testing with informed participants using simulation microworlds. Research subjects comprise graduate business students and practicing managers.

Through a deeper understanding of the dynamics of interventions the research seeks to identify and derive "patterns of interventions" which would assist in decision-making and effective formulation and implementation of interventions in complex systems.

BOUNDED RATIONALITY

According to Simon (1957), “bounded rationality is a property of decision making that reflects people’s cognitive limitations. Individuals faced with complex choices are unable to make objectively rational decisions”. The reasons for this are as follows:

1. They cannot generate all the feasible alternative courses of action;
2. They cannot collect and process all the information that would permit them to predict the consequences of choosing a given alternative; and
3. They cannot evaluate anticipated consequences accurately and select among them.

Morecroft (1983) carried out a study on the philosophy of human decision making expounded by the Carnegie School.[i] “Underlying the work of the School is the powerful notion that there are severe limitations on the information processing and computing abilities of human decision makers. As a result, decision making can never achieve the ideal of perfect (objective) rationality, but is destined to a lower level of intended rationality.” (Morecroft, 1983)

Along with the above arguments related to bounded rationality, Morecroft (1982, 1985) identifies six common practices that underlie the shortcomings of the human decision making process. They are:

1. Factored (fragmented) decision making

Complex issues are divided up into pieces (eg, disciplines, sections, departments, etc) to facilitate decision-making, as “they cannot be handled by an individual”.

2. Partial and certain information

Decision makers tend to use “only a small proportion of the information that might be relevant to full consideration of a given situation”. They would also “avoid the use of information that is high in uncertainty”. This tends to focus the decisions on problem symptoms and locally optimum solutions.

3. Rules of thumb / Routine

This refers to situations where decision makers, under time pressure, resort to “quick fixes” in order to rectify a situation as quickly as possible. Quick fixes often result in “backfire” or unintended outcomes.

4. Goals and incentives

Focus on certain goals and incentives could compromise other areas and undermine the performance of the larger system.

5. Authority and culture

Culture and tradition provide powerful predetermined frameworks for decision makers (i.e. mindset, mental model). Through customary routines and commands, prevailing values and traditions are transmitted to all and hence get reinforced and further ingrained.

6. Basic cognitive processes

“People take time to collect and transmit information. They take still more time to absorb information, process it, and arrive at a judgment. There are limits to the amount of information they can manipulate and retain. These cognitive processes can introduce delay, distortion, and bias into information channels."

To deal with the above shortcomings, many authors have suggested ways to improve the effectiveness of human decision-making. These include, among other tools, management and computer frameworks (Gilberto, 1995, Cayer, 2001), computer simulation models (Simon, 1987, Sterman, 1988), and the use of systems thinking in decision-making (Senge, 1990, Maani, et al 2004).

STUDIES OF INTERVENTIONS

MISPERCEPTION OF FEEDBACK

A classic work in this area is Sterman's research (1989) in relation to the "misperception of feedback". A simulation model, known as the "Beer Game", was used with groups of participants to investigate their interpretation of information feedback and the effects on the interventions derived.

"The decision making task is straightforward: subjects seek to minimize total costs by managing their inventories appropriately in the face of uncertain demand." (Sterman, 1989) In such a "simple" environment, however, things did not always go as planned for most participants, due to the rich simulated environment, which contains "multiple actors, feedbacks, non-linearities, and time delays." (Sterman, 1989) Similar to Morecroft's and Simon's idea about factored decision making, "the interaction of individual decisions with the structure of the simulated firm produces aggregate dynamics which diverge significantly and systematically from optimal behavior." (Sterman, 1989).

The findings of the study are summarised into the following points (Sterman, 1989):

- Subjects failed to account for control actions, which had been initiated but not yet had their effect.
- Subjects were insensitive to feedbacks from their decisions to the environment.
- The majority attributed the dynamics they experienced to external events, when in fact these dynamics were internally generated by their own actions.
- The subjects' open-loop mental model, in which dynamics arise from exogenous events, is hypothesized to hinder learning and retard evolution towards greater efficiency.

THE IMPROVEMENT PARADOX

Keating et al. (1999) carried out a study of the effectiveness of improvement programs. The motivation for the study arose from the fact that "most attempts by companies to use them [improvement programs] have ended in failure" (Easton and Jarrell, 1998 in Keating et al., 1999), and that even "successful improvement programs have sometimes led to declining business performance, causing layoffs, low morale, and the collapse of commitment to continuous improvement." This dilemma was termed the "Improvement Paradox".

The study was carried out on major companies to understand why improvement programs often fail. The findings suggest that "the inability to manage an improvement program as a dynamic process – one tightly coupled to other processes in the firm and to the firm's customers, suppliers, competitors and capital markets – is the main determinant of program failure. Failure to account for feedback from these tightly coupled activities leads to unanticipated, and often harmful, side effects that can cause the premature collapse and abandonment of otherwise successful improvement programs." The study, however, does not suggest that improvement programs are ineffective in terms of improving organizations. In fact, the authors point out that "firms with developed quality programs significantly outperform their counterparts in profitability, share price and return on assets." The problem lies in the suitability of these programs and the style with which they are implemented.

LEADERSHIP AND INTERVENTION

In a recent HBR article, Kanter (2003) reports on several companies which have experienced major declines in their fortunes, declines which have been successfully reversed by the interventions of their new CEOs.

These companies, although from different industries and differing in size, experienced similar patterns of decline in their business. Often decisions were made by various functions or divisions (as in "factored decision making" [ii]) to employ quick fixes (as in "rules of thumb") to various problems in order to achieve short-term goals within tight time limits (as in "goals and incentives"). For example, a common practice at Gillette was to offer "discounts to retail customers at the end of a quarter in order to move products and achieve sales targets, thus sacrificing margins and jeopardizing the next quarter's sales".

The author has suggested that the use of common practices as rules of thumb (as in the Gillette case) is very common in troubled companies. These short-run solutions usually make the situation worse in the longer term. For instance price cuts from discounts, although they would be effective in increasing sales, would also reduce the funds available for marketing, which increases the organization's reliance on the promotional deals. Customers will also know that they can wait until quarter's end to get even better deals.

The resulting deterioration in morale and work culture can be termed "learned helplessness". People in the organization feel that there is little they can do to make a difference in the company and therefore become passive. This in turn reinforces the decline of the organization - a vicious cycle that could lead to ultimate downfall.

RESEARCH METHODOLOGY

In order to explore the complex dynamics in managerial interventions, an experimental research approach in conjunction with a computer simulation model has been used in this study.

The use of simulation models in experimental research as an alternative to laboratory and field experimentation has become common. In these simulations, participants are exposed to real-world experiences where "manipulation [of independent variables] and control are possible … [and] the course of activities is at least partly governed by the participants' reactions to the various stimuli as they interact among themselves." (Sekaran, 2000)

EXPERIMENTATION TOOL

The experimentation tool used in this research is a computer simulation model known as the Service Quality Microworld (SQM), developed by MIT System Dynamics Group and used by the authors for several years in executive courses. SQM simulates the operations of a generic service company. The simulation starts at a "steady state" where incoming orders, orders completed, work backlog, rework, hiring, personnel turnover, time pressure (employee), monthly profit, and monthly expenses are held at a constant rate. Appendix A shows the partial Causal Loop Diagram involving the input variables.

The research subjects are graduate business students who were invited to take part in the experiments. At the time of this writing 15 participates had completed the experiments - they comprise the sample group for this report.

Each experiment session lasted 2-3 hours during which the participants could manipulate the values of three "input" variables: net hiring (monthly), quality goal, and production goal, thus causing changes in the 'output' variables, listed above, through the complex and dynamic relationships amongst them.

The simulation is advanced on a monthly basis for up to 60 months. Players can manipulate any/all of the three input variables over time in an attempt to achieve defined goals, such as maximizing cumulative profits, minimizing rework, or improving productivity. Numerous results are generated instantaneously through SQM reports and graphs.

At the outset of the experiments the participants were encouraged to use the learning cycle comprising: "Conceptualize – Experiment – Reflect" in developing their decisions and interventions (Maani, et al, 2000).

DATA COLLECTION

In the experiment sessions, the participants were required to perform certain tasks to achieve the stated goals using the simulation microworld. The subjects worked individually during the experiments with no breaks so no information exchange and "interaction effects" were expected to occur. Data were collected on:

- Demographical information about the participants;

- Strategies devised by participants for carrying out the task(s) and/or achieving the goal(s) in the simulation model;
- Actual interventions carried out in the experiment on the simulation model;
- Outcomes and results on the simulation model; and
- Participants' interpretation and comments relating to the interventions and outcomes/results.

The above include both quantitative and qualitative data, which will facilitate a triangulated perspective of the research questions.

RESEARCH EXPERIMENTS

For the experiments the participants were required to achieve the stated goal of maximizing cumulative profits over the period of 5 years by implementing various interventions with respect to the three input variables, namely, Net Hiring, Production Goal and Quality Goal.

There were two separate exercises involved in each experiment session:

Exercise One: Participants were asked to achieve the goal by intervening with *only one* of the three variables (Net Hiring, Production Goal, and Quality Goal) over the course of the 5 years in the simulation. They were free to choose any of the above three.

Exercise Two: Participants were asked to achieve the goal by intervening with any combination of the three variables over the course of the 5 years in the simulation.

In both exercises, participants were asked to develop a strategy before starting the simulation. The subjects were asked to record their strategies on the worksheets provided, which shows a detailed log of their decisions, actions and results. Also, they were asked to *predict* the likely behaviour pattern of their chosen KPIs over the course of the simulation. Subjects were monitored inconspicuously during the session.

Once the planning step was completed, the participants were asked to record a schedule of their interventions on a time line. That is, *when* and *how much* change in the chosen input variables they were planning to implement.

At the end of the simulation run, they were required to record the stated outcome of the experiment (i.e., the cumulative profits at the end of year 5), and comment on the result as well as the process. This information was also recorded on the appropriate worksheet.

Of particular interest to the research question were two key measures by which "intervention" was quantified. First, the Frequency Variable measured the number of changes made during the course of the experiment. Second, the *Style Variable*, a measure of average percentage change, representing the extent and magnitude of changes made. The value of each variable, recorded by the subjects themselves, was converted into an index (with a base value of 1 for the initial default value). The style variable is then calculated as the average change in the index during the five years of the simulation. Hence, the larger the index, the larger the degree of intervention made by the subject in the system.

Following the experiments, the strategies of the participants were examined by scrutinizing the graphic outputs of their KPIs, the three input variables (Net Hiring, Production Goal and Quality Goal), and other measures computed in the simulation, such as Total Personnel, Orders Completed, Actual Quality, Time Pressure and Rework. As SQM is a systemic model, all these factors are dynamically interrelated.

These outcome patterns were then studied against the original strategy developed by the participants to examine whether:

1. They had adhered to their original strategy throughout the experiment; and
2. To what extend the simulation results were consistent with their anticipated outcomes.

Any discrepancies from the original strategy and their expectation were noted and studied closely to find out more about the mental model of the participant, and how the information 'feedback' influenced the participant's decisions during the course of the simulation.

Preliminary Results

The full results of the experiments for Exercise One are summarized in Appendix B. From this table, the best and worst results (cumulative profit over 5 years) are shown below (Table 1) and contrasted with the base-line performance (steady state - no change).

Table 1 – Best and worst sample results compared to base-line performance

Sample results	Style	Frequency	Cumulative Profits
Worst performer	0.718	17	- $20,294,781
Best performer	0.077	3	$13,129,626
Baseline performance	0	0	$13,125,000

A cursory examination of the results shown in Appendix B reveals some consistent and powerful patterns of causal relationships. For example, the notions that the larger the number of interventions (the "Frequency" variable), and the larger the extent of change (the "Style" variable), the poorer the outcomes ("cumulative profit") are strongly evident.

To test this statistically, a multiple regression model of Frequency and Style as independent variables against Cumulative Profit as dependent variable was run which confirmed the above observations. The multiple regression results are summarized in Tables 2 and 3 below:

Table 2 - Output from regression analysis on Style, Frequency, and Cumulative Profits (Exercise One)

Experiment	n	R^2	F	Sig. F	Variable	Coefficient	t-stat	p-value
Exercise One	15	0.5646	7.7791	0.0068	Style	-21196968.67	-3.0365	0.0103
					Frequency	-418431.7985	-3.5647	0.0039

Table 3 - Output from regression analysis on Style, Frequency, and Cumulative Profits (Exercise Two)

Experiment	n	R^2	F	Sig. F	Variable	Coefficient	t-stat	p-value
Exercise Two	15	0.4701	5.3238	0.0221	Style	-42269496.7	-2.8175	0.0155
					Frequency	-260310.051	-1.9804	0.0711

As the table strongly indicates, the model as well as the two independent variables is highly statistically significant even at the lower significance level of 0.0711 (to higher significance level of 0.0039). What is remarkable and did surpass the author's expectation is the high level of R^2 achieved with only two explanatory variables within a sample size of 15 participants! That is, in the simulation experiments, 47% to 57% of variations in cumulative profits, over a 5-year period, could be reliably explained by the style (i.e., extent) and frequency of managerial interventions. A closer inspection of the participants' monthly profit patterns (not shown here), adds considerable explanation power to the regression models. Further, taking into account other qualitative variables (see summary table for Exercise One in Appendix A) adds further prediction capability for sustained profit performance in the long term. This aspect will be explored in future papers. It must be noted that, in the above experiments, variations in performance are primarily due to the interaction dynamics between the input variables and internal system variables and do not arise from stochastic elements in the model. [iii]

These results, although at this stage still preliminary, go a long way towards refuting the first two and the most fundamental research propositions of this study, namely:

1) Extent of change (Style): Dramatic change should lead to dramatic (positive) results.
2) Frequency of change (Frequency): The more change initiatives (i.e., more interventions), the better the results.

In other words "*over-intervention*" is counter-productive.

Currently, further research is in progress to test this theory using other microworlds as well as investigating real life case studies to validate the robustness of the preliminary results reported above. Should the results hold true under different microworlds and real cases then they would have far-reaching managerial and organizational implications and could shed new light on what would constitute a theory of intervention in social systems.

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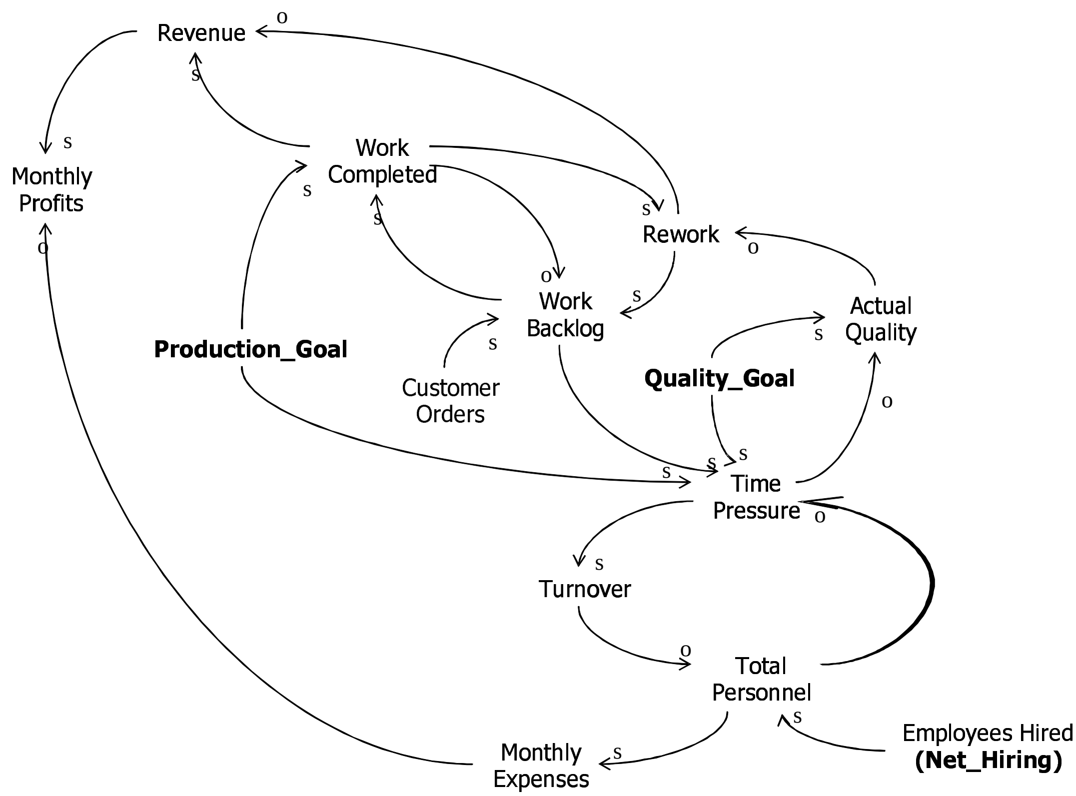
APPENDIX A

Partial Causal Loop Diagram involving the input variables for SQM



APPENDIX B

Experiments Summary: Exercise One

ID	Style	Frequ-ency	Para-meter	Soft Variables Noted	Appreciation of Delays	Short Term Results	Sequence & Timing	KPIs	Cumulative Profits
01	0.077 Major changes	3	HR	TP	Not mentioned	Reacted to the reduction in Profits by lowering HR	Good (increase capacity early).	Profits, TP, RW	$13,129,626
02	0.507 Big increments, for prolonged periods	43	QG	AQ	Not mentioned (the adverse effects of the increase in QG came after a short delay)	Participant did not react to the fall in Profits immediately. (Should have stopped increasing QG).	N/A	Profits, RW	$-12,617,236
03	0.028 Major changes with small adjust-ments	43	PG	AQ	Not mentioned (delayed effect of increased PG)	Did not react to the drop in profits immediately.	N/A	Profits, OC, RW, AQ.	$2,566,367
04	0.718 Big changes	17	QG	AQ, TP, %E	Not mentioned (build up of TP due to increased QG came at a delay)	Responded to drop in profits by increasing QG	N/A	Profits, PT, RW, WB, OC, AQ	$-20,294,781
05	0.031 Small changes	52	PG	TP, AQ	Not mentioned (Adverse effects of TP came at a delay)	N/A	Prolonged increase in PG, resulting in negative effects.	Profits, WB, RW, TP, PT, AQ	$-16,581,752
06	0.090 Big & small changes	37	PG	%E, TP	Not mentioned (delayed effects from build up of TP)	Tried to lower PG to gain short term results in lowering TP. Resulted in a failure	Lowering of PG at beginning was unwise	Profits, OC, RW, WB	$-7,751,501

07	0.01 Incremental (continuous) without much reviewing	59	QG	AQ, TP	Not mentioned (delayed effects of increase in TP)	Treated the initial short term increase in profits as sustainable. As soon as profits fall, QG was reduced.	N/A. The feedback from the system was ignored.	Profits, PT, TP	$-3,970,629
08	0.073Small changes with one major change	17	QG	TP	Not mentioned (build up of TP)	Responded to the lack of short term increase in profits by reducing QG. Unwise.	N/A	Profits, TP, PT	$-7,978,145
09	1 Major changes	5	QG	Not mentioned	Not mentioned (delays in improvements and TP)	Did not react according to short term results. Strategy implemented regardless of the outcome	Increase in QG is too big & frequent, since employees are not experienced	Profits, AQ	$-10,831,849
10	0.458	4	QG	Not mentioned	N/A	Worsened situation was not noted until the 5th year. Radical interventions were deployed then.	N/A	Profits, AQ	$-5,071,931
11	0.028 Small changes	5	QG	Not mentioned	Not mentioned	Reaction to slight drop in profits during months 51-53 by major drop in QG. Too excessive	N/A	Profits	$11,876,724
12	0.077 Small changes	6	HR	TP	Not mentioned (increase in HR has led to an increase in OC which reduces WB, contributing to the reduction in profits at end)	**The fall in profits at the beginning has led to an increase in HR, when in fact, it is the extra hiring that has caused the fall in profits.	N/A	Profits, OC, TP	$11,688,783
13	0.8 Big changes	5	QG	TP	Not mentioned (the delayed effects of the increased initial QG)	The initial success in profits has led to more increase in QG	N/A	Profits, AQ	$-5,303,774
14	0.246	5	HR	%E	Noted the delay in training of rookie employees	Did not act according to short term results	Good. Waited for effects to happen (%E)	Profits, OC, AQ	$11,294,976
15	0.718 Majo								

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