LEVERAGING SYSTEM DYNAMICS ARCHETYPES IN CASEMIX SIMULATION MODELING

Maliapen Mahendran
Graduate School of Business, Curtin University of Technology, Perth, Australia

Mohammed Quaddus
Graduate School of Business, Curtin University of Technology, Perth, Australia

Ram Ramaseshan
Head School of Marketing, Curtin Business School, Curtin University of Technology, Perth, Australia

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Abstract

Unlike that of most management science methodologies, the focus in systems thinking is not on 'solving' problems or seeking an optimal solution. Conventional problem solving does not explicitly consider the context of the problem. This implies that the "hospital financial management problem" could be neatly isolated from its environmental and external factors. System thinking and system archetypes, in contrast, acknowledges the messiness of the world and views a problem in the context of its environment. This is one reason why qualitative variables play an important role in system thinking, as these variables represent conditions or phenomena that cannot be measured or accounted in a strictly quantitative approaches .In this paper we present specific healthcare system archetypes which consider such external influences in the healthcare industry in Australia and observe their behavior over time.

Introduction

In system thinking, lev*erage* refers to actions or interventions that can have a lasting impact on the system in terms of reversing a trend or breaking a vicious cycle. This has much deeper implications than merely finding a solution to a problem, as leverage often requires fundamental and long-term changes to the system and not merely removing the symptoms of a problem. In health care, for example, we can attempt to "solve' the waiting list in for radiological CAT scans by applying the queuing theory and creating discrete simulation models to minimize waiting times. However a *key* cause of the growing waiting list was rooted, partly, in the lack of co-operation amongst health providers, which lead to poor capacity management and resource utilization. The latter requires systemic thinking and consideration of multifaceted structural changes. Systems thinking and modeling make it easier to see these leverage points in order to create relevant intervention strategies. The cases described in detail in this paper discuss the process of casual loop modeling and defining archetypes in the context of different healthcare policy issues and demonstrate the use of leverage points in creating intervention strategies.

In the discipline of system dynamics, causal maps have been used mainly as a bridge between system insights and system modeling (Richardson and Pugh 1981, Roberts et al 1983, Wolstenholme 1990). Systems archetypes '.. reveal an elegant simplicity underlying the complexity of management issues - [they] recondition our perceptions, so as to be more able to see structures at play and to see the leverage m those structures.' (Senge, 1990:pp 94 -95). Systems archetypes are generic systems models or templates that represent a wide range of situations. Systems archetypes also provide a high-level map of dynamic processes. Using the analogy of language to illustrate systems thinking, we can say that while *variables* are 'words' (building blocks) and pairs of variables (and the connecting arrows) are sentences, causal loops are stories, and *systems archetypes* are common phrases. Systems archetypes have been developed by the System Dynamics Group at MIT. There are eight systems archetypes that are commonly used, and we refer to these archetypes by the names used by their originators.

Progression to System Archetypes

We specifically wanted to focus on the dynamic hypothesis and model improvement by casual loop analysis. The desire to capture various political, social, environmental, societal factors and other qualitative people factors such as preference for a specialist, patient loyalty, referrals by word of mouth, productivity of hospital staff were not understood clearly and we had not used an "operational thinking" approach to quantify these factors. In addition, we had felt that many processes had interconnectivities and feedback to other parts of the model and these were not succinctly understood. We, therefore, used system dynamics archetypal models as a reference to verify the feedback loops and to assess if the model structure could be simplified and standardized based on these archetypes.

By understanding the performance of archetype, we were able to bring some generalizations to the model for instance some parts of the model worked almost like independent molecules and others like molecules interacting with each other, some taking inputs and others providing outputs.

Hospital managers realized the value we were bringing to their strategic decision making process by including the qualitative factors. The feedback on the model results for the second stage was mixed, as there is much subjectivity in determining the scales, ranges and initial values for the qualitative variables.

Dynamic hypothesis and Casual Maps

Recently, the value of a causal map in its own right is rapidly gaining ground (Coyle 1998, 1999). A system dynamics archetype can be defined as a molecular building block of stocks and flows for a model structure. With the publication of *The Fifth Discipline* (Senge 1990), there was dearth of interest in using the science of archetypes, explicit system modeling of complex issues can achieved by examining the whole system. The goal is to understand how the feedback structure of a system contributes to its dynamic behavior. The stocks and flows, the polarities of feedback loops interconnecting them, and shifts in the significance or dominance of various loops in the structure help contribute to this understanding. Causal maps for systems archetypes tend to use abstract variables (Meadows 1982, Kim 1992, Senge 1990).

At a molecular level, there are two distinct types of causal loop structures namely balancing andreinforcing loops. The behavior mode of a simulation at any given time is determined by the strongest feedback loop(s). Simulation implies implicitly the operational model (Richmond 1993).The overall pattern of behavior over time can be related to changing relative strengths of feedback loops. The causal map can be built with less time and efforts than a simulation model and it can give important insights and understanding that clients demand (Coyle 1998, Eden 1988). A system with one balancing and one reinforcing loop produces S-shaped development if the reinforcing loop dominates in the first phase, and the balancing loop dominates in the second phase. So, its representation is consistent and universal. Causal maps for system archetype are famous for their simple structure and rich insights. However, they cannot show any behavioral implication and thus do not allow any behavioral experimentation (Lane & Smart 1996).

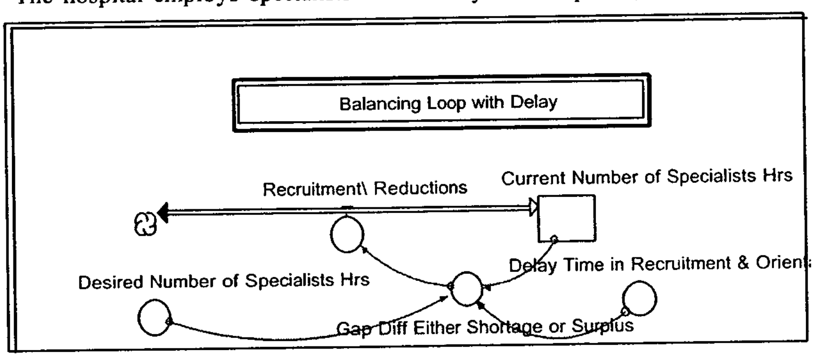
Based on these, there is taxonomy of subsequent archetypes, which can be developed. Theseinclude Limits to Success, Escalation, Growth & Under investment, Drifting Goals, Balancing Loop with Delay, Fixes that Fail, Successes and Successful and Tragedy of Commons. The taxonomy is simply based of the types of casual loops i.e. reinforcing or balancing or both that occur within these archetypes. Archetypes that consist of only balancing loops are the Balancing Loop with Delay, Drifting Goals and Escalation archetypes. In the reinforcing loop only category, we have Success to the Successful and Gro wth & Under-investment archetypes. In the hybrid category, which consists of both types of loops, Fixes that Fail, Limits to Success, Shifting the Burden and Tragedy of Commons.

Healthcare System Dynamic Archetypes

In the casemix model of the hospital, we discovered that some that some of the phenomena as described by these archetypes could be represented. Although in some cases it required some amount of modification of the models to demonstrate similar behavior. We say similar because it some cases it was difficult to get the exact behavior. We shall discuss these findings. By sorting the elementary modes according to strength, we identified the dominating behaviour of the model (Myrtveit & Saleh 2000).

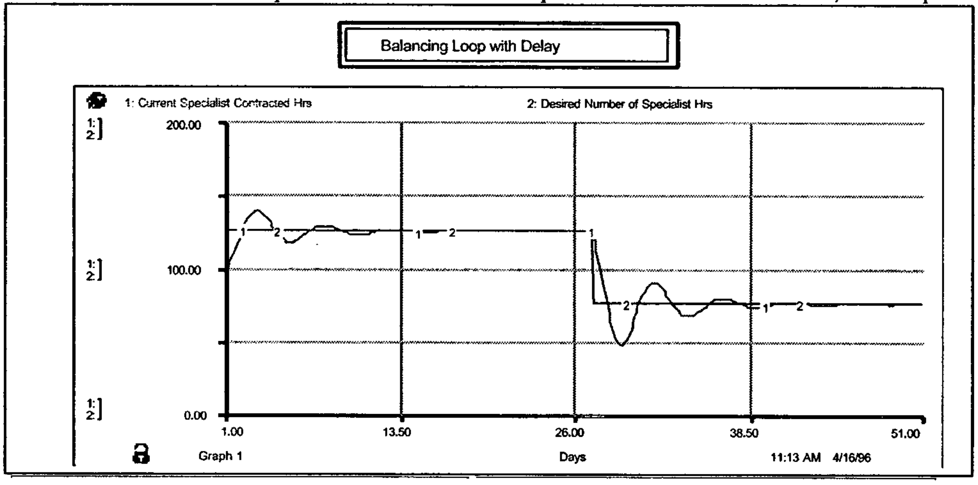
BALANCING LOOP WITH DELAY

The hospital employs specialists in a variety of disciplines, which include orthopedic surgeons, ophthalmologists, obstetricians, gynecologists, pediatrians, neurosurgeons, cardiologists, pathologists etc. Each of these specialists has a committed figures for patient numbers, utilization of beds and operating theaters and required to deliver against those agreed targets in return for admitting rights or privileges. There would be many such specialists operating within the bounds of their economic deliverables within each Diagnostic Related Group. There are issues of policy decision making as the specialists who have the leadership positions in



patient preference rankings are not only expensive in terms of procedure charges but also have longer waiting times due to patient demand. But coincidentally, these are the specialists for hospitals to target, as they are likely to bring greater revenue and a commanding medical reputation to the hospital. As a consequence, these specialists have many different admitting rights contracts with the hospitals.

In the case of the balancing loop with a delay, at an aggregated level for the hospital, the current number of specialists' hours describes the product of total number of specialists with admitting over the period of the simulation and the contracted hours and represented as a stock. As patient admissions fluctuate, these specialists' hours increase or decrease to cope with the demand as shown on the graph. The difference between the required specialist hours for treatment and the contracted specialists hours will create a gap. However, in reality this gap cannot be filled immediately and there is inevitably a time delay for the hospital after its recruitment action. If the delay is greater than the time constant, the gap will never close and model demonstrates oscillating behavior. i.e. because of the time taken to issue more specialists with admitting rights and the orientation required, the patient load or demand requires more specialists.

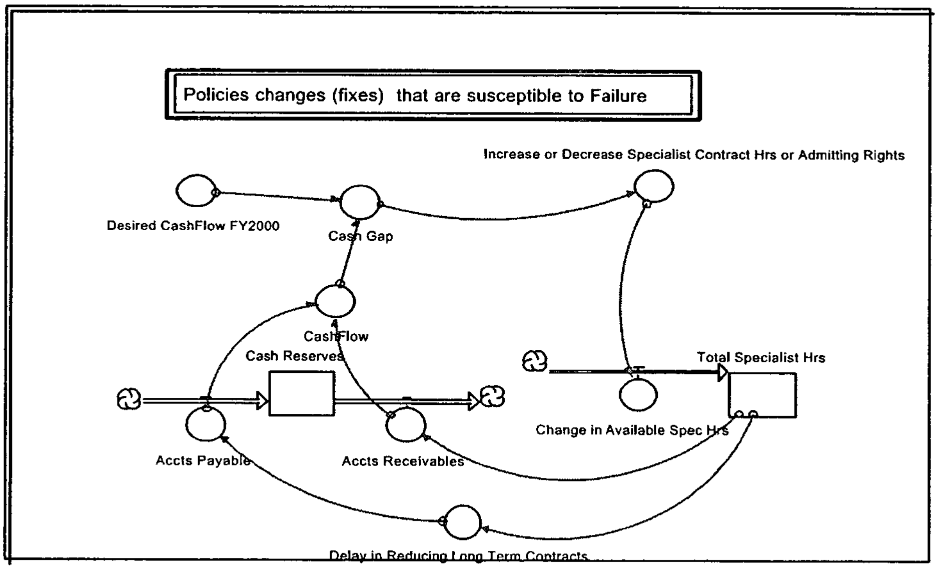


In this sort of situation, more patients get turned away form admission to other hospitals. If the time for action is less than the time constant then we have a dampening effect and the system behavior achieves an equilibrium or steady state. The corollary to this behavior is when the gap is negative and the resultant action is to reduce contracted hours although we were advised this rarely happens in real life. Admitting rights contracts are usually long term in nature.

FIXES THAT FAIL

In the case of the Fixes the Fail archetype, we determined that an increase or decrease of the specialist contract hours will also result in reduction or increase in revenue streams. In its representation, this archetype is characterized by a balancing structure offset by a reinforcing structure, which acts after some delay.

We assume that the hospital is experiencing some cash flow problems, so the cash flow for fiscal year 2000 has a target greater than the current cash flow. The hospital management has two alternatives which is it can either cut costs which results in reduction of resources or it increase revenue (Rodwin, 1995).

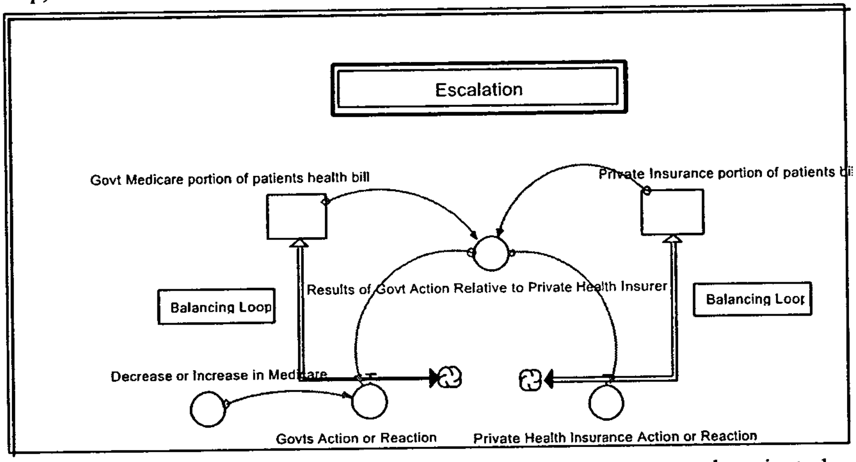


As evidenced by the simulation graph, a reduction in the contracted hours of the specialists has the immediate effect of increasing cash flow but cash flow soon decays away over the next few time periods. So the inner circle is the balancing loop that seeks to achieve the desired cash flow for fiscal year 2000. But reduction in specialists who have long-term contracts will take some time for the effects to be seen and there is a delay in realizing its cash flow. The viscous outer reinforcing loop, in time, dominates over the gains of the inner balancing loop.

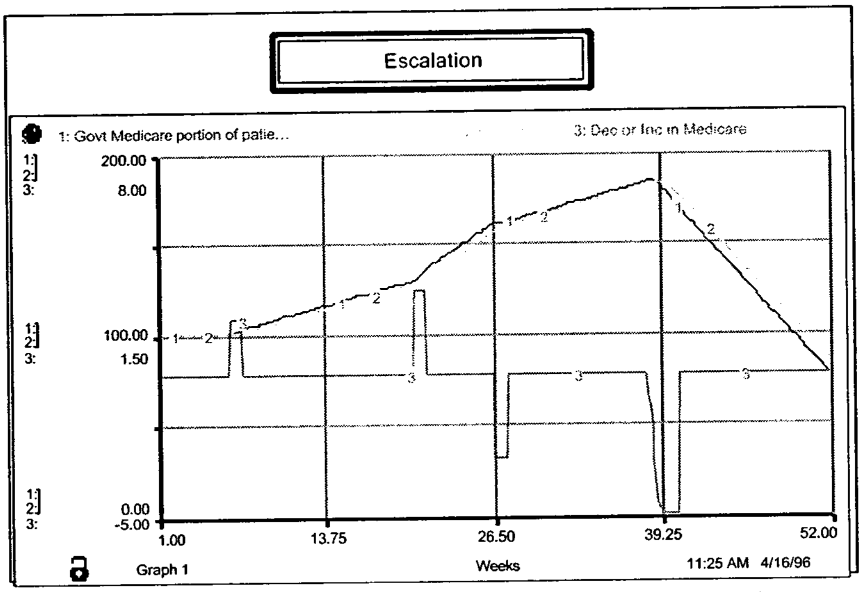
However it may appear counterintuitive but if the hospital management chose to increase its specialists using a locum pool of specialists instead of the "knee-jerk" reaction of specialist reduction, then the simulation graph shows that there is an initial reduction in cash flow but the recovery in revenue gains eventually improves the longer-term cash flow position of the hospital.

ESCALATION

The escalation archetype is represented by two balancing loops that interact in a manner to produce a single reinforcing loop, which is either viscous or virtuous depending on the polarity of the balancing loops. In analyzing the loop structures of the casemix model, the private health insurance companies and Medicare Australia are key players in funding treatment of private patients (Taylor & Morrison, 1993). Up to 1999, Medicare funds up to 75 % for majority of Commonwealth Medicare Benefits Scheme (CMBS) codes of the private patients health bill and up to 85 % is funded by private health insurance which leaves a 15 % "out of pocket" patient gap. So there will be great instability in the healthcare market if either the government or the private health insurers reduce the coverage or funding that they currently extend to patients.

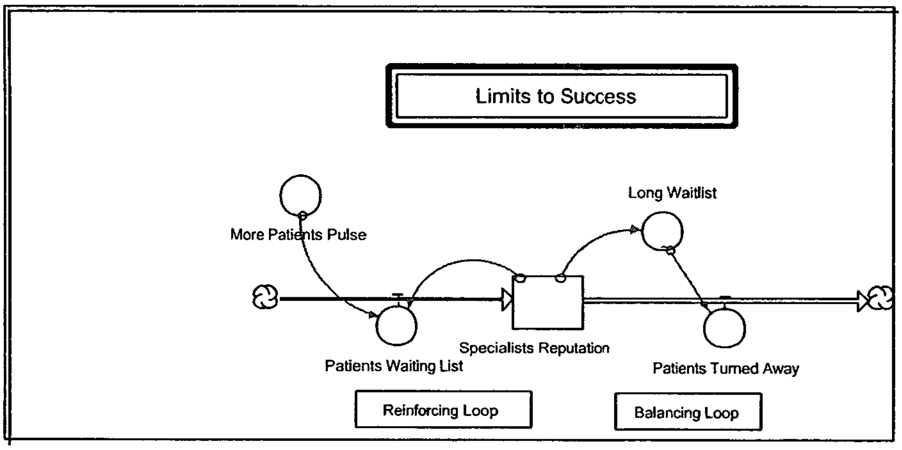


The behavior of the structure is stable until a sudden pulse or fluctuation is introduced and based on the Governments announcement to say reduce Medicare funding, then the Private Health Insurers respond with a cut in their funding. Fortunately, such instability has not occurred but to the contrary, where the Government announced that Australian taxpayers will be eligible to a tax rebate if they subscribed to a private health fund. As a consequence of Governments action as seen on the simulation graph is a pulse, private insurers reacted positively as they were getting greater market share and with economies of scale and new subscriptions. Also, private insurers introduced a "no gap" scheme in conjunction with the medical fraternity. There now exists a list of specialists where there is no "out of pocket" gap for the patient. Such is the ability of simulation modeling that helps us model and understand such unique responses to social engineering.



LIMITS TO GROWTH

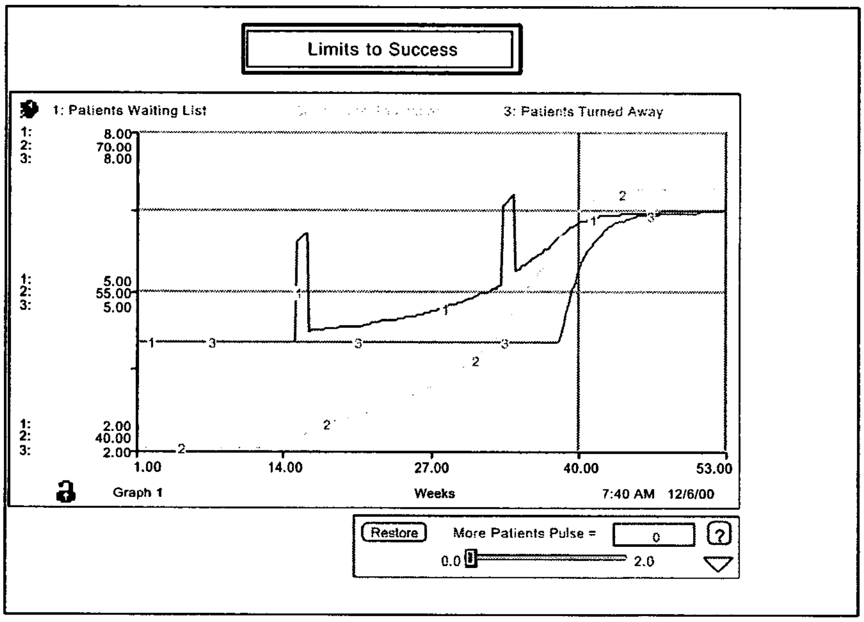
Good reputable specialists treating any health illness or disorder are in high demand and market research shows that a good deal of this reputation is developed thorough good "doctor-patient" rapport which in turn gets spread by "word of mouth" of referrals. This is typically common in an industry so heavily dependent on personal relationships. However good specialists also have their share of problems that is they are in very great demand and only the expensive hospitals can afford them on their payroll. For the patient this translates into a penalty of a long waiting time, which means the patient has to endure pain and agony for a longer period of time. Additionally, it can be very expensive as the "out of pocket" gap would be much higher. Hence, this can be regarded as a "limit to growth" for the specialist.



The Limit to Growth archetype is characterized by a reinforcing loop, which is offset by a balancing loop. The reinforcing loop initially shows an improved performance as the more patients turn up at the doors of the reputed specialist. It in turn swells the patients' waiting list, and patients get turned away due to the uncomfortable waiting periods for their hospital admissions and treatment.

In exploring the casual loop structures for the casemix hospital system further through the interaction of healthcare managers, we discovered the balancing loop with delay is in existence in several other business processes within the hospital model e.g. admission delays, training delays and patient billing or fee collection delays and this "Balancing Loop with Delay" archetype has been substituted where its occurrence was relevant.

The "Fixes that Fail" archetype was also present when hospital managers attempts to reduce its cost structure per DRG by reducing cost weights in order to improve cash flow. This inevitably is unsustainable and the effects are lost in a few time periods. In addition, any increase of cost weights or length of stay (LOS) above the national average will reduce government funding based on the casemix data (Shortell & Kalunzy, 1994).



Another occurrence of the "Limits to Growth" was discovered when we simulated the increase volume of patients to increase the revenue streams which had been contained by the previous bed capacity and the quality of care being given both of which were limiting factors to continued sustainable growth. In fact, the admissions of patients' decreases slightly when the perceived quality of treatment has dropped in the health institution in multiple Diagnostic Related Group's (DRG) case and is particularly pronounced if a only single DRG is simulated.

Conclusion

System archetypes definition for a given network of feedback loops, where the relative strengths of the loops change over time, can be used to determine the underlying characteristic behavior. The structure, behavior and reasons for shifts in loop dominance are three important keys to learning from archetypes.

Richardson (1994) contends that formal analyses based on eigenvalues were used to identify dominant structure and in Eberlein's work, to reduce a complex model to a simpler structure while preserving particular behavior modes of interest.

In a sense, *simplifying a complex structure while preserving a behavior of interest* is one way of saying what we mean by *understanding the connections between structure and behavior.*

When it comes to model structure, it is quite common to subdivide a model it into sectors or subsystems and analyze its behavior such that the topology of the model is clearer. Each part of the casemix simulation model has been studied and understood independently at a detailed level, while the overall relationships between the parts can be described at a higher level. There are five defined sectors in the Casemix Model, where archetypal approach has been applied. These are Patient Admissions, Casemix Market Influences, Murdoch Market Share, Medical Staff, and Patient Relationship Management.

Planning for survivability in hospital systems must be approached from a holistic perspective (Schine,1995) The dimensions of planning process will extend to clinical, economic and sociological interactions, as the private market becomes an increasingly competitive environment. The large volume of casemix data available can be put to good use to generate test case scenarios for the future. However, hospital policymakers must be weary that such simulation models can, at best, be described as tools for decision support, which will help strengthen their arguments in the boardroom.

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