Modeling the Impact of Knowledge-Based Innovations:
The Case of Best Practices Implementation in a Small Health Care Private Practice

Ignacio J. Martinez-Moyano[1]
Doctoral Student
University at Albany
im7797@albany.edu
(518) 442-5257

Gary Wadhwa
Maxilofacial Surgeon
Adirondack Oral & Maxillofacial Surgery
awadhwa1@nycap.rr.com
(518) 424-2940

Abstract

This study uses a group model building approach to create a dynamic theory of the impact that the implementation of knowledge-based innovations has on the behavior of a small health care private practice centered in customer value and service quality. The development of the model generated an increase in the employee awareness of the impact of their work in the organization, and a preliminary understanding of the dynamics of innovation implementation in the firm. However, by the end of the study, the complete interconnectedness of the system was not yet clear for everyone. The results suggest that in small health-care practices, like the one studied, to pay attention to the feedback processes in place in the organization, to manage innovations in a purposeful way, and to manage the relation with the environment have important influences on the success of innovation implementation. The system dynamics model developed—presenting an endogenous theory of how service organizations influence their demand—for the study is explained.

Keywords: Health-Care Dynamics, System Dynamics, Innovation, Implementation, Best Practices

Antecedents

It appears that a common practice in the management of small health care private organizations, is to rely on personal ability specifically related to the core theme of the practice itself (e.g. pediatrics, general dentistry) and ignore other sources of knowledge and information to be able to provide better care for the patients. These practices often generate unexplained behavior that the directors of small organizations have to cope with. These medical leaders, because of their medical orientation, tend to minimize or even ignore those things, concentrating their efforts on the 'important' things of the health-care practice. Often times, in order to provide better health care, the most important thing is to pay attention to the managing implications related to providing health care. Especially, to pay attention to the feedback processes in place within an organization that condition the results that one can encounter (Richardson, 1991).

In the organization that we developed the system dynamics model discussed here, several cues were present telling us that the dynamic behavior of the organization was not the intended and that a new approach was needed to understand the underlying structure that was creating the observed behavior. Employee's stress and turnover were on the rise, frustration of senior management was soaring, and there was an evident lack of alignment between the employee's vision of the organization goals and the management goals, among several other things. A hypothesis was made that, in this organization, frustration with the implementation of improvement programs and unintended consequences of those programs created interesting distinct dynamics worth studying.

[1] Corresponding author at imartinez@gproyectos.com.mx or im7797@albany.edu

The organization that we studied was established in 1994 and has offices in Albany and Clifton Park, New York. Its total financial growth was 1200% from 1994 to 2001 (see Figure 1) with 26 employees. The products the company offers include: oral surgery implants, oral pathology, and facial cosmetics in their office practice, and they provide hospital based facial trauma, tumors, and reconstructive surgery. The work requires a high degree of labor intensity, interaction, and customization in order to provide high value service to their customers and third party actors like insurance companies and the community at large. This organization was doing something radically different from others of its kind. The practice, under the leadership of the managing partner, was implementing knowledge-based innovations from other industries in their own health-care practice. This health-care organization was on its way of implementing Quality Six Sigma initiatives; lean manufacturing principles, balanced-score-card evaluation processes, customer service initiatives, and value-chain development ideas (for examples of innovation implementation in different industries see Cobbenhagen, 2000).

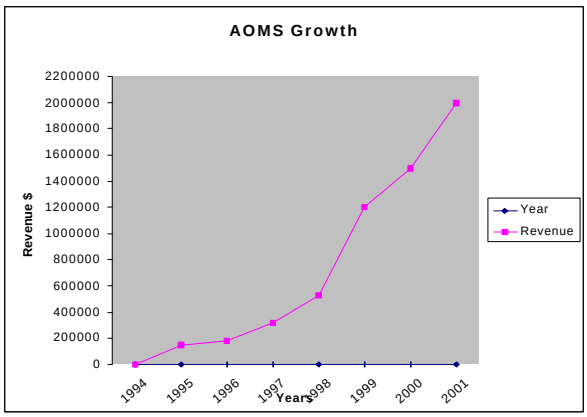

Figure 1—Growth Pattern

The dynamics played out in a way that customer dissatisfaction, due to a lower quality of service caused by an explosive growth of the firm, was increasing. Additionally, a high employee turnover, and increasing referring-doctors complaints created enough pressure to demand a deeper explanation of what was going on in the organization. System Dynamics provided an excellent lens which exploring the structural causes of the behavior could be addressed adequately. After significant growth for 6 years, in 2001 (see Figure 2) reputation and financial success showed a decline despite the company's vision to be recognized as quality leader in service and value for their patients and the emphasis on implementation of improvement programs—Quality Six Sigma, balance scorecard, Lean.

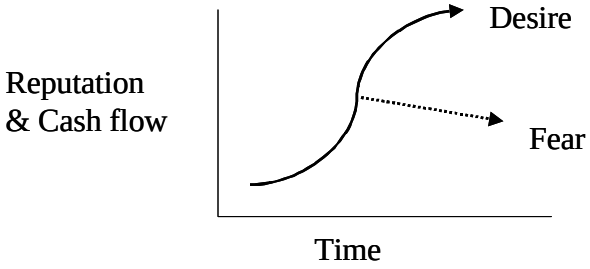

Figure 2—Motivation for Study

Theoretical Framework

The development of the model was approached using SD (System Dynamics) as the base approach to generate a dynamic hypothesis of the behavior of the small health care practice, and also were used the University at Albany's Group Modeling Techniques (see Andersen and Richardson, 1997; Andersen, Richardson and Vennix, 1997).

Process and Products

We developed a plan to create a system dynamics model with the client group. This plan was aimed at being able to make them 'own' the model and the results from it in order to obtain the best possible use of their time invested in this project and to create research through real action in the organization (for action research elements see Argyris, Putnam and Smith, 1985; Argyris and Schön, 1996). We did this in one-hour weekly meetings with the managing team for two months prior to meet with the staff for a whole-afternoon meeting in which we built the first version of the model presented. During those sessions, the group agreed that the products that the modeling effort would try to generate were:

1. Structural Understanding of the elements that causes the behavior of the Health-Care Practice.
2. Dynamic Understanding of the practice.
3. A policy testing instrument to enhance the practice's strategic planning capabilities.
4. A means to increment the development of the firm's organizational intelligence.

Organizational intelligence is related to how information and knowledge shapes policy, it includes both scientific knowledge and political or ideological information that helps create the way the firm rationalizes the opportunities it faces, determines its goals, and establishes the adequate structure and control to achieve the results it wants (Wilensky, 1967).

Understanding the System

The Key Reference Modes

To understand the system through a group model building approach, one key element is to elicit the variables and reference modes of importance to the group (Andersen and Richardson, 1997) in an effort to capture their view of the *reality* of the system. The group, as the more relevant for the sturdy, selected four variables; these are (1) employee workload, (2) employee productivity, (3) perceived quality, and (4) net earnings. The group created reference modes for these variables expressing their desires and fears with respect to the behavior of the variables. Figures 3 to 6 show the reference modes for the variables. The desire is identified with a dashed line and the fear with a solid line.

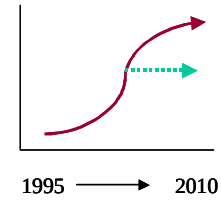

Figure 3—Employee Work Load

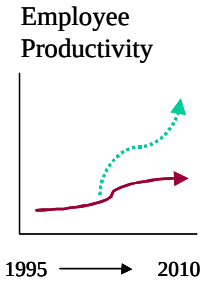

Figure 4—Employee Productivity

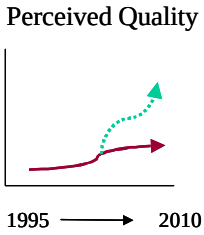

Figure 5—Perceived Quality

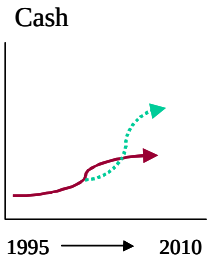

Figure 6—Net Earnings

According to the group, workload has been increasing while the productivity has stalled influencing the perception of quality and driving earnings to stagnation. With these four variables in mind and using the concept model as elicitation device, we worked with the group to create a feedback-centered understanding of the dynamics of the organization. Eight major causal loops were identified with the group.

The Causal Loops

The single most important process in the system is the growth process. The growth loop (Figure 7) represents a causal explanation of the growth of the firm under study. New patients feed the backlog of patients to be treated that increment the treated patients that contribute to the word of mouth that, through its effect influence the referrals that increase the new patients flow.

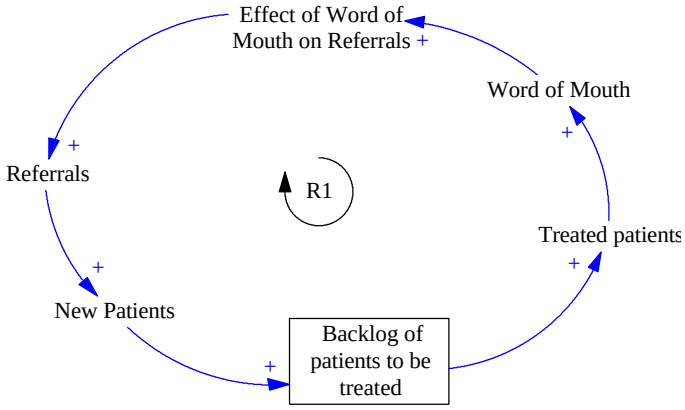

Figure 7—Growth Loop

Growth, explained in part by the word of mouth affecting the referrals, is also related to the networking that the firm creates with both referring doctors and insurance companies. Figure 8 presents the insurance networking loop that captures some of the relationships present in this processes. The possibility of delighting the costumer through specific procedures and the management of the expectation of value create a good word of mouth effect that, with the participation in insurance plans, create more referrals that increase the overall growth of the firm.

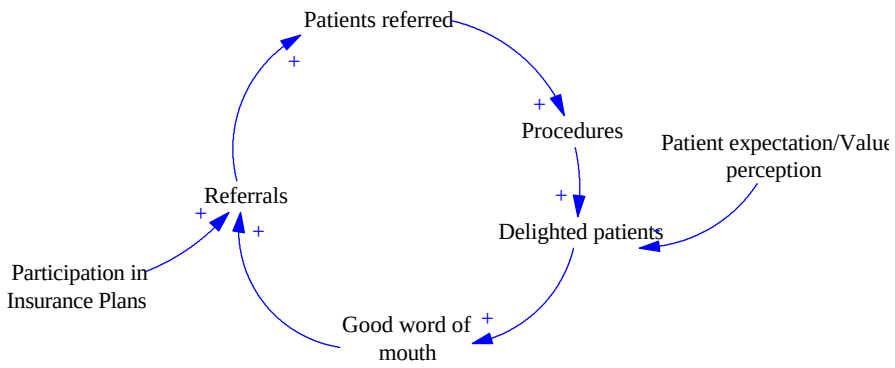

Figure 8—Insurance Networking Loop

By accepting a greater number of insurance plans, allowing for a minimum out-of-pocket expense of patients, and providing high quality care, the perception of value of customer is high incrementing the likelihood of becoming a ‘delighted’ customer.

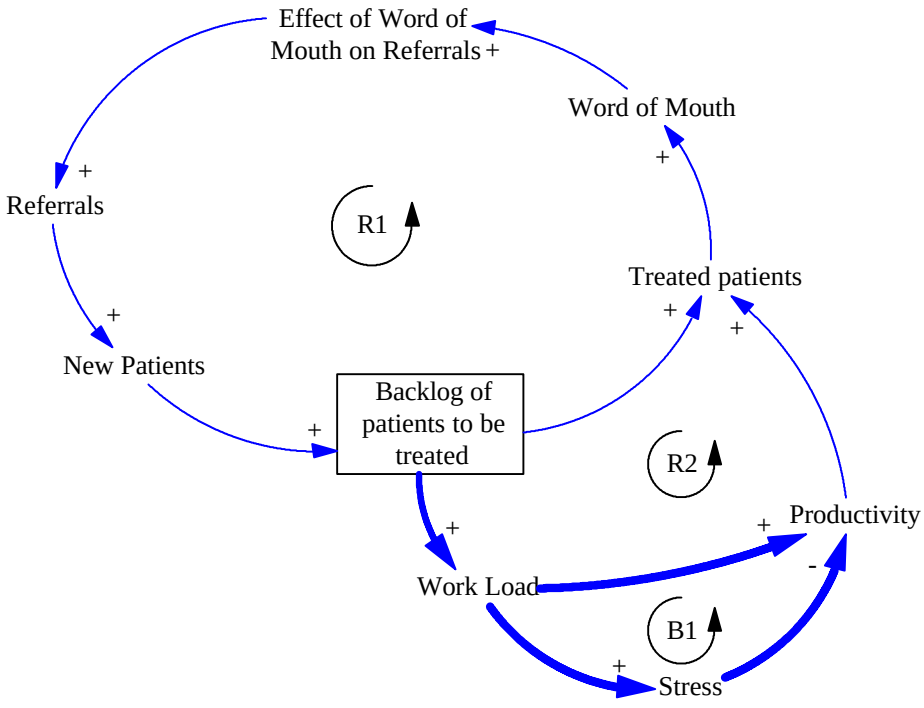

Figure 9—Productivity Loop

Growth processes in organizations have several side effects that can undermine the benefits obtained. In Figure 9—the productivity loop—an explanation of some of the effects of growth, as perceived by the modeling group, is depicted. More new patients influences the backlog of patients to be treated, increasing the workload which has an effect on stress and productivity, that in turn influences the number of patients that can be treated. Growth pains that are created include, among others, space constraints, increased workload, and overcrowding in facilities.

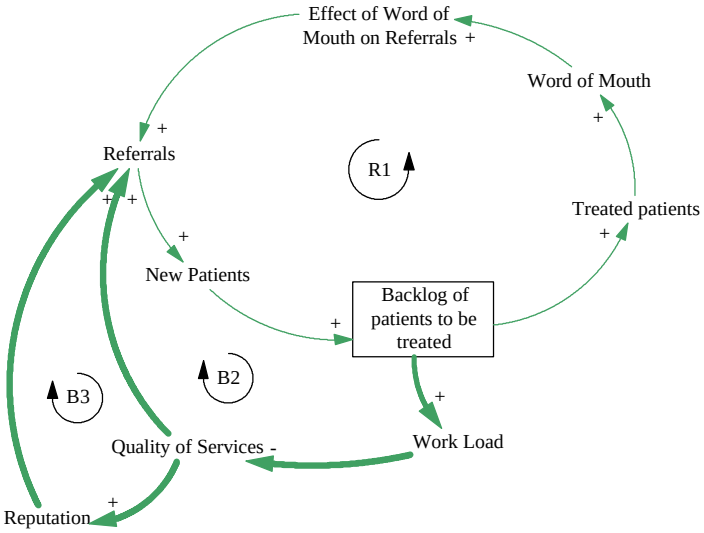

Figure 10—Quality Loop

Growth in the firm influences the level of the workload that also influences the quality of services provided (see Figure 10). Quality affects the reputation and the number of referrals, which is a major driving force for new patients. During the course of innovation implementation processes, more innovative initiatives further increase the workload that already stresses the work force workload creating pressures on quality and future growth of the firm.

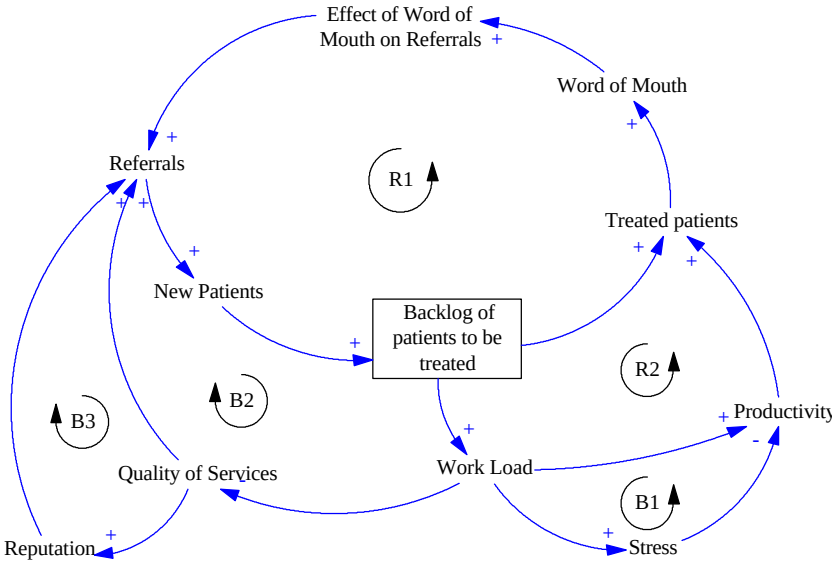

Figure 11—Workload Loop

In the firm, the workload loop (see Figure 11) is a central loop in explaining pressures on growth processes and dynamic behavior observed. Workload influences productivity and quality of services, becoming a key element to stress generation and overall quality of the services provided.

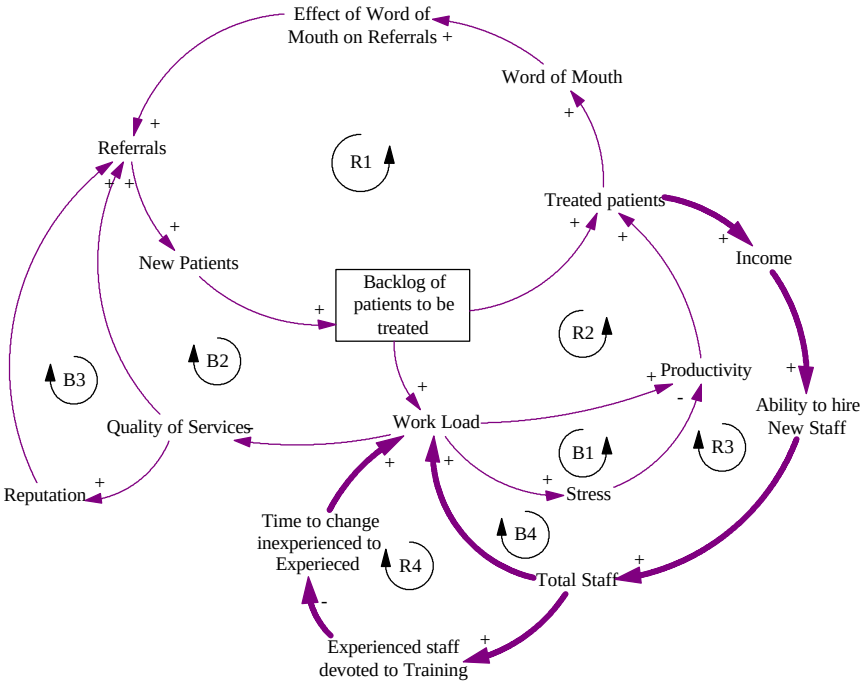

Figure 12—Productivity/Staff Loop

Figure 12 shows the productivity/staff loop that allows us to clarify the effect that staff have on productivity and the way in which the different pressures are generated. As the number of treated patients grows, available income increases, influencing the ability to hire new staff; and through an augmented total staff, influence the workload. This is positive in the sense that staff will have enough time to deliver quality services and stress levels could go down. However, more staff also means experienced staff must provide training to inexperienced staff in the specific processes of the firm. General knowledge can come from the labor market but specific knowledge related to the firm has to be provided by experienced individuals within the firm (Brickley, Smith and Zimmerman, 2001, pp. 341-342).

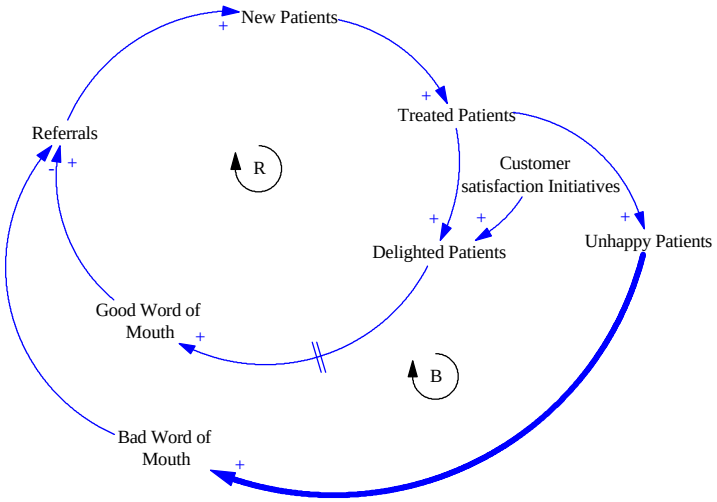

Figure 13—Bad Word of Mouth Loop

An important unintended consequence of growth is the increasing of unhappy patients due to the overall increase of patients (see Figure 13). Having more patients increases the probability of having unhappy patients at the end of the process. Unhappy customers can create a very fast decline in reputation and referrals through bad word of mouth effect. Unhappy customers are more likely to influence new customers than happy customers because they can display a strong emotional component while commenting on the quality of the service. Additionally, there is very little delay in reaching the referring doctors compared to delighted customers. With growth, unhappy patients increase and negative word of mouth can create a major problem by becoming dominant in the mode of behavior.

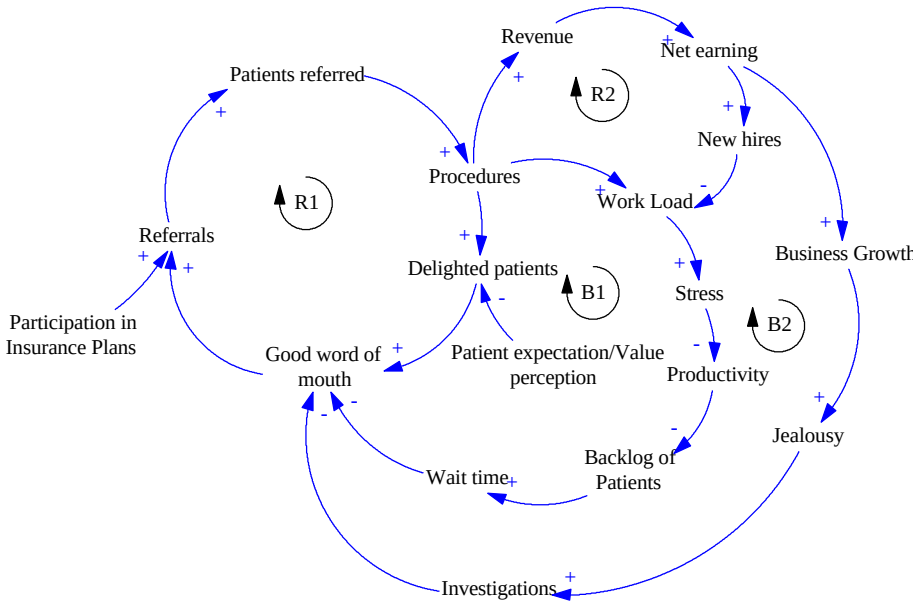

Figure 14—Jealousy Loop

One last loop that the group considered crucial in explaining the dynamics of growth of the firm is, what they called, the jealously loop presented in Figure 14. With business growth, jealously increases influencing the number of investigations with respect to procedures that eventfully can influence the word of mouth about the practice. Jealously is related to what other practices of the same type (pediatricians, dentists, etc) may do when they know about the growth and success of a fellow practitioner. The possible actions include 'advising' customers not to go there, advising insurance representatives to take a closer look at the operations reported by that practice, create 'interesting' stories about unhappy patients of the practice among others. This type of behavior can be considered unethical but can be very real.

After exploring all of the loop explanations of the system's situation, a system dynamics model was built to further understand the relationships and to operationalize the loop-based explanations.

The System Dynamics Model

The Model has been conceptualized in five Sectors (Operations, Community, Knowledge-Based Innovation Projects, Human Factor, and Financial) Figure 15 shows the sector diagram.

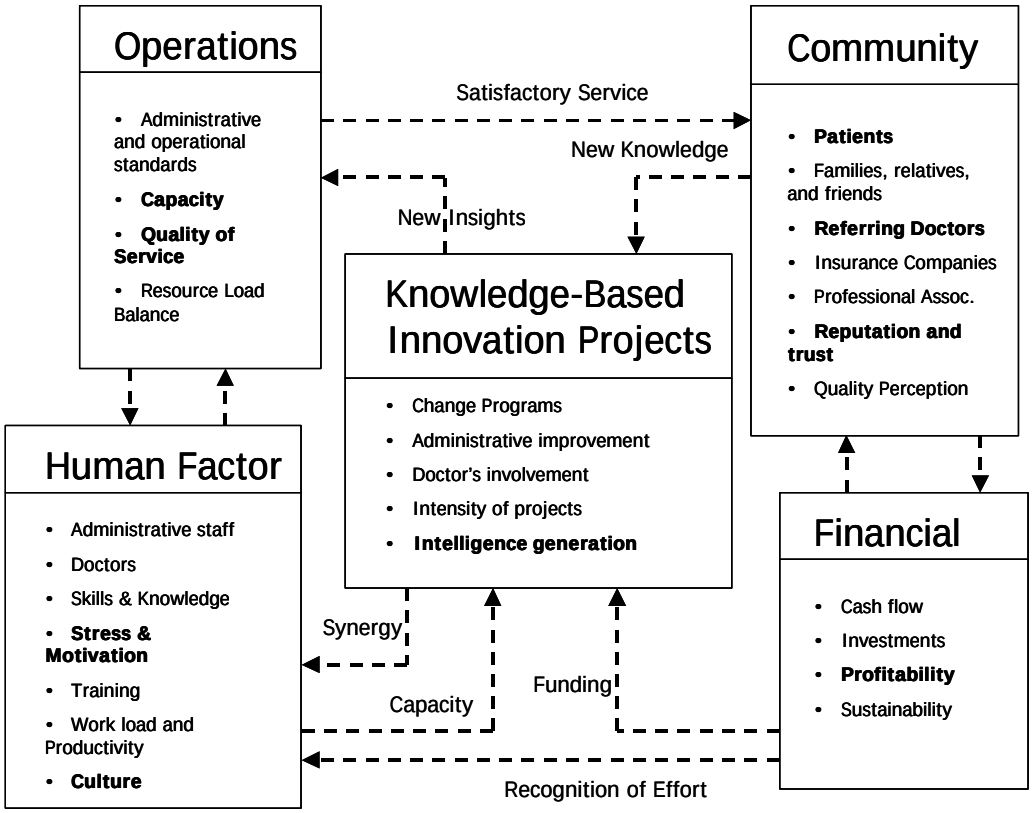

Figure 15—Sector Diagram

The model was focused on these five sectors for the development of the detailed model. The Financial sector concentrates around stock of cash at hand. The cash flow statement takes into account the earnings after all the expenses. This stock is dependent upon many factors. The most important relationship is with the community. The better the reputation and customer satisfaction, the more revenues would be generated. The expense side of the equation is dependent upon the operational efficiencies of the organization. The increase in cash can result in investment in future capacity of the organization. The capacity in terms of space, employees, and their skills can all be increased. The skills in taking care of customers, programs that measure and modify the behavior of the employees towards delighting the customers depend upon, among other things, the cash available to the organization.

Patients, their friends, and relatives, referring doctors, businesses that employ these patients, the insurance and other health care agencies represent the community around the organization. The reputation, in this line of activities, is like building brand awareness and loyalty in the community. The word of mouth of the reputation is a powerful factor that can increase or decrease the number of patients coming to see the doctors in the practice. The word of mouth of the reputation can also influence the referral behavior of the referring doctors that are key to the success of the practice. The group, regarding its ‘softness’ and appropriateness, questioned the use of word of mouth as a model variable. We pointed the appropriateness and previous uses in system dynamics models of soft variables in the literature (for examples see Sterman, 2000).

‘Operations’ is where six sigma, lean manufacturing, and quality initiatives are implemented. The initiatives are implemented to improve the efficiencies that can result in decrease in expenses. These initiatives can also lead to load balancing and proper resource

distribution that could result in more customer satisfaction and employee satisfaction. The skills learned in the operational efficiency can help improve the capacity without changing the physical location. The different levels to be addressed are the environment (external to the firm), the firm (internal organization), and the specific project (six sigma, lean manufacturing, etc). These three broad levels are identified as relevant to create a successful innovation process (Cobbenhagen, 2000, p. 227).

All the sectors are related to Human factors. The people have to execute the projects and provide excellent customer service. The training and motivation of the people is an important factor in development of the practice. The trained and motivated employees will perform better and produce more. If the stock of employee skills increases, the financial results of the organization can have a spectacular shift in nature. The performance measurements linked to Economic Value Added is a key motivational factor to improve the productivity of the practice. The knowledge-based innovation projects are geared towards operations and human resources. These projects are designed to increase the overall organizational intelligence.

The sessions with the management team allowed us to sketch a concept model that was presented to the larger group. After the presentation of the concept model, more sessions were conducted and a final version of the model was developed.

The Concept Model Used

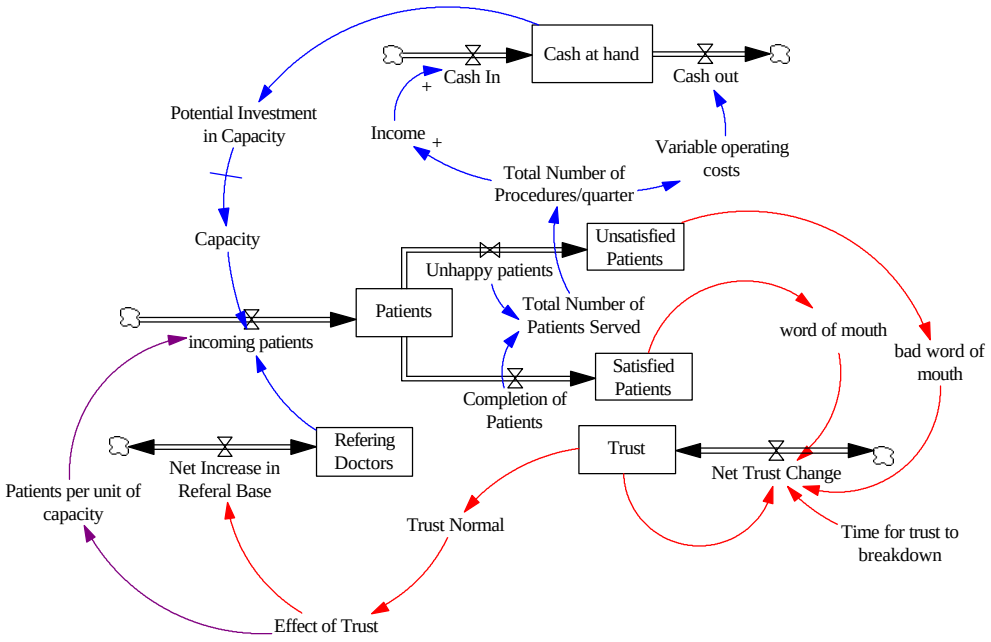

Figure 16—Concept Model

The model was created incrementally with the group focusing in what they thought was most relevant. The patients stock is the central part of the model because it identifies the essence of the practice ‘to heal patients’. The experience of the patients was disaggregated into two categories: unsatisfied patients and satisfied patients. All these patients contribute to cash generation, that in turn, influences the capacity and the possibility of having more incoming patients. *Referring doctors* is an exogenous input at this point.

The group considered the effect *patients*, through word of mouth, has on the level of Trust the community has on this practice. The level of Trust, in turn, is a major influence on the referring doctors base. This health-care practice is a specialized practice depending on the referring doctors to complete the cycle of the patients, once loosing their Trust, the incoming patients flow would suffer dramatically. The recognition of the 'Trust effect' created a major impact on the group when the behavior was presented.

The discussion of the group on the 'trust effect' on the community generated very interesting elements. These included among others, how to identify the time that takes to create trust, what is 'trust' and how to create it, the time that takes to breakdown trust in the community, and the concept of 'standard' or 'normal' trust and how it evolves through time in the relationships that the practice has with the referring doctors, and the community in general. The focus was on the identification of the elements that the practice could actually 'see' and measure that could give them knowledge to make 'intelligent' decisions and allocation of resources for the future. After this, we gave them some time to 'digest' this 'trust effect' euphoria and then continued in the process of adding important links that they saw that were missing in the 'picture' of the structure.

In the last version (see Figure 16), a 'self-confidence' of trust was captured by linking the effect of trust to the number of patients per unit that the practice could attend. The rational was that in 'trustful' times, the overall efficiency of the system could be incremented by a motivated workgroup that was confident that was doing the right things inside and outside of the practice.

The Structure of the Final Model

The structure of the final model is presented in three parts, the patients-tasks structure; the patients backlog structure, and the satisfaction structure (see Figures 17, 18, and 19).

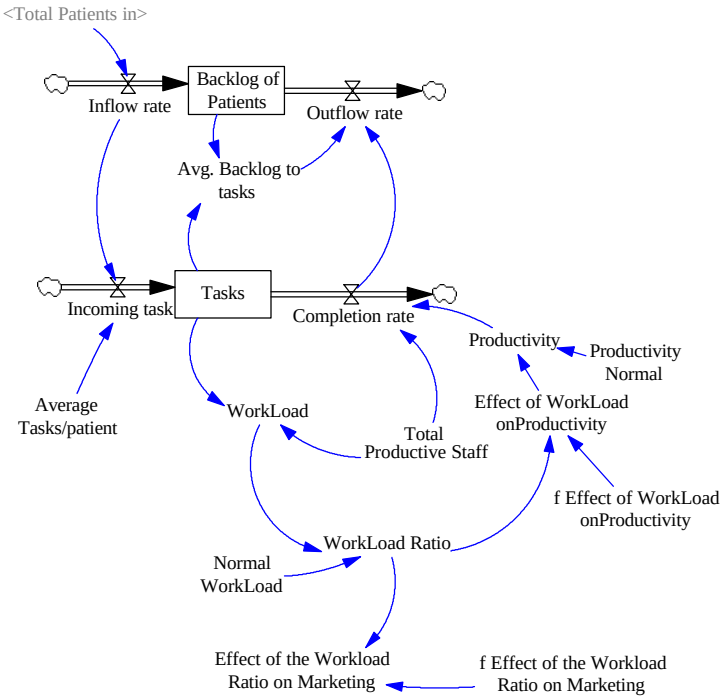

Figure 17—Patients-Tasks Structure

Figure 17 shows the patients-tasks structure that relates how the inflow of patients having a certain number of tasks per patient to be performed on them moves the dynamics of the practice. 'Tasks' is modeled as a co-flow of backlog of patients that influences the workload and is affected by the productivity; this level represents the total number of activities that the practice performs.

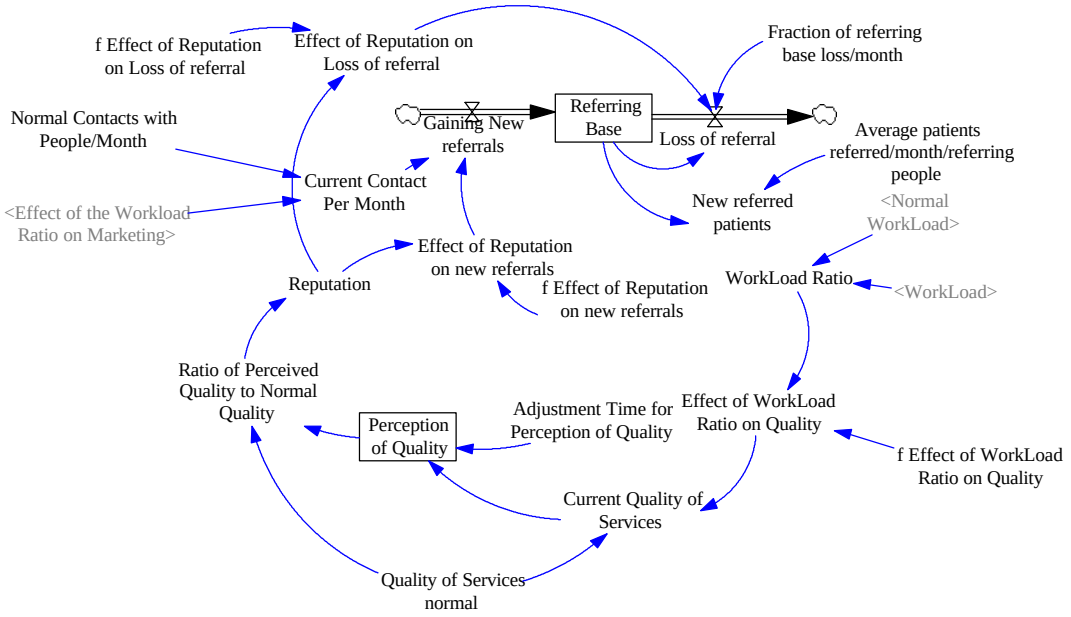

Figure 18—Referring-Base Structure

The referring base is computed by the difference between the referrals gained and those lost in a certain period. The reputation of the firm influences both the gained referrals and prevents losses of already active referrals. The ratio of perceived quality to normal quality determines the reputation that influences the referrals. Workload influences the quality of services and reputation.

The way referrals are conceptualized represents an endogenous theory of how service organizations influence their demand. In this case, quality of the services provided plays an important role.

In Figure 19, an endogenous view of incoming patients with the effects of satisfied patients and doctors' behavior is presented. In the system under study, the number of contacts is crucial to generate the relationships with the referring doctors that feed the patients pipeline. Patients, satisfied and unsatisfied, are the main element driving the behavior over time of incoming patients. This insight was considered by the group as extremely powerful to acknowledge and act on it. Before the modeling effort, most of the members of the group deeply believed that 'new patients' came *tabula rasa* to the practice and that 'served patients' went 'outside' and never had any influence again. Now, they are sure that there is a powerful connection between patients—old, current, and new—that allow the practice to grow and improve over time.

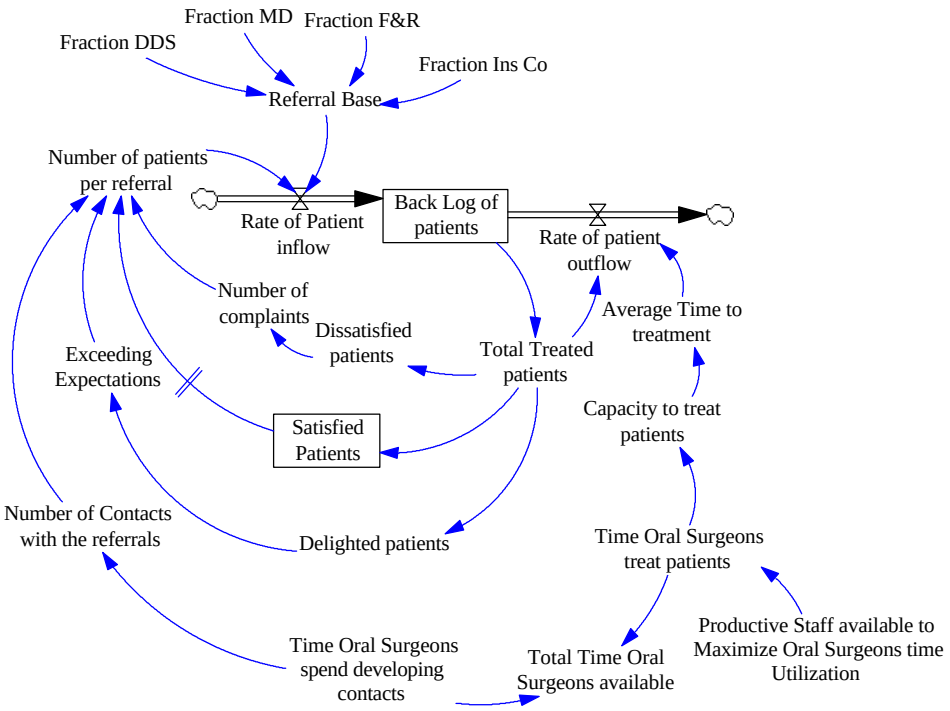

Figure 19—Satisfaction Structure

The Behavior of the Model

The modeling effort was conducted following standard practice to enhance quality and confidence in model results (for an explanation of the process followed see Martinez and Richardson, 2001, p. 3). Figure 20 shows the behavior of the model in equilibrium.

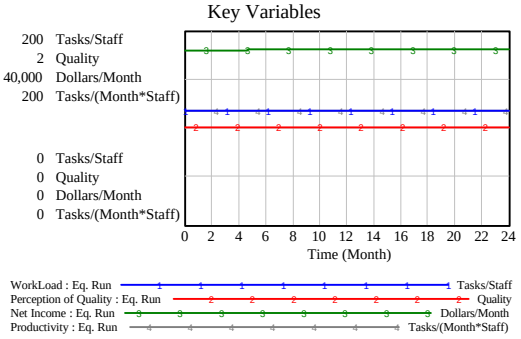

Figure 20—Equilibrium Rum

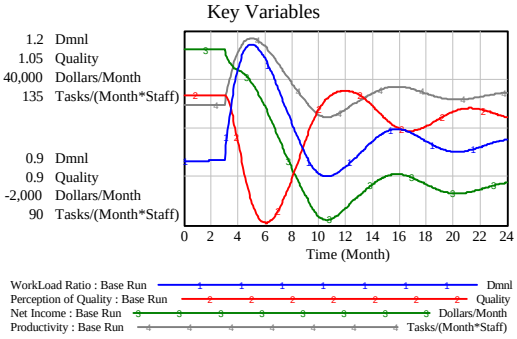

Figure 21—Base Run

The base run considers a 20% increase in the average tasks per patient. This run is considered the base because due to the implementation of innovations and increased administrative controls the average number of tasks that the firm has to perform has incremented. In Figure 21, the consequences of the increase are presented. The change in tasks per patient creates a damped oscillatory pattern in the variables of interest. Income, perception of quality, and productivity suffer from this change and workload increases creating a non successful view of the practice. Innovation and uncertainty go hand in hand; successfully implementing

innovations require a different management style and organization than the one used in steady-state processes (Cobbenhagen, 2000, p. 277) . Companies should recognize this and change the way they conduct business during the process—steady-state equilibrium, transient-state dynamics, and new equilibrium of the firm.

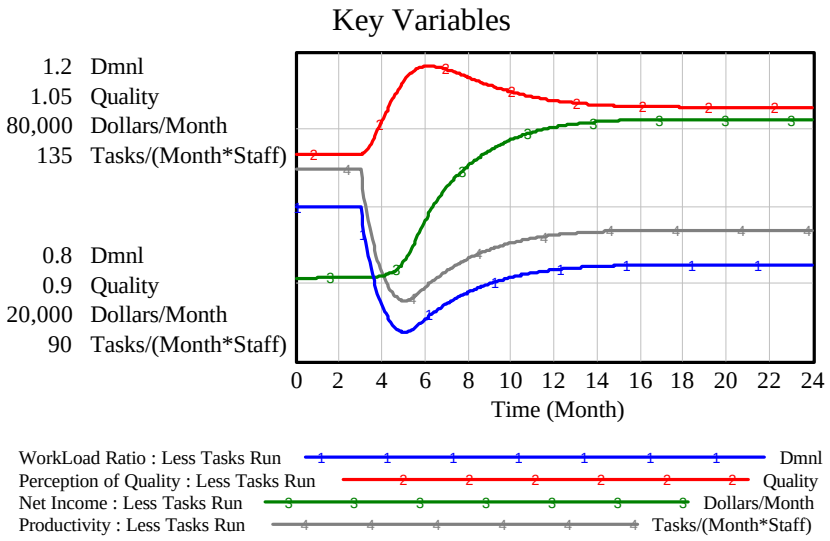

Figure 22—Less-Tasks Run

Figure 22 show the behavior obtained when a 20% decrease in average tasks per patient is simulated. This run—less-tasks run—represents the successful implementation of the innovation. In the case that we studied, lean manufacturing techniques are the innovation that, if successful, can decrease the average number of tasks per patient in the firm contributing to new dynamics of the firm. Perception of quality of the firm and net income increase in a significant way while the workload ratio drops and the overall productivity decreases[2].

In order to identify successful innovations, we need to know what does it mean in the context of the firm. Cobbenhagen (2000, p. 71) offers a definition of it as being 'the economic exploitation of innovation' and saying that it is difficult to identify a way to understand the *successfulness* of the innovation in firms. Based on the results of the study conducted, we say that successful innovations are those that can act as levers for the attainment of goals that are dynamically coherent and systemically desirable (Lane and Oliva, 1994) in the context of a culturally-feasible change.

According to Cobbenhagen (2000, p. 273) three elements are necessary to create successful innovations, a strong knowledge base, to proactively manage innovations, and to be able to manage the relation with the environment. The improved run shown in Figure 23 uses these concepts to create better behavior of the system. In this new run, a 20% decrement in the average tasks per patient is simulated along with doubling the average number of contacts per referring doctor from 11 to 22. These changes assume that the innovation is proactively managed (the lean concepts to decrease the number of tasks), that a strong knowledge base is created (to actually induce the changes), and that the relation with the environment is managed adequately

[2] This decrease is related to the way productivity is computed. See appendix one for details on the formulation of the model.

(by means of increased contacts with refereeing doctors). This improved run is just a first approximation to a more complete exploration of the complex set of combinations and possibilities present in this case study. It is now clear that innovation management comprises many ingredients from complexity—large number of variables involved, tightly interrelated in non-linear fashion, and highly dynamic—that makes it both an interesting research theme and particularly suited for being studied using system dynamics (Milling, 2002, p. 85).

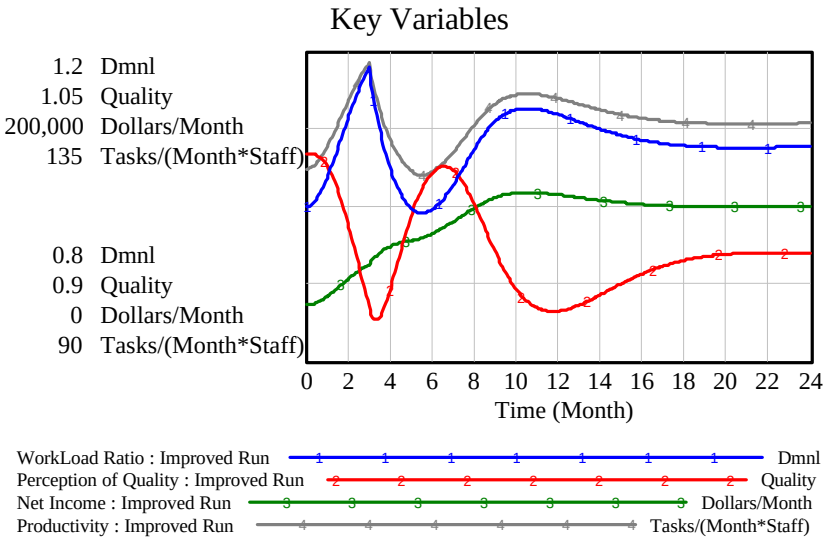

Figure 23—Improved Run

The dynamics of the improved run are more ‘stable’ than previous runs, the damping oscillations are heavier tending to equilibrium much more rapidly. Figure 24, 25, and 26 show the results of the different runs to the system’s behavior, workload, net income, and average quarterly profits are presented.

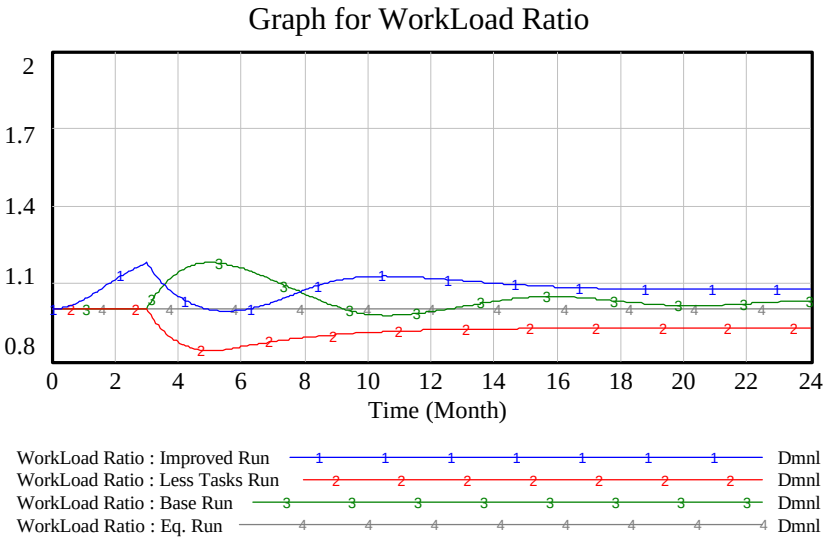

Figure 24—Comparative View of Workload Ratio

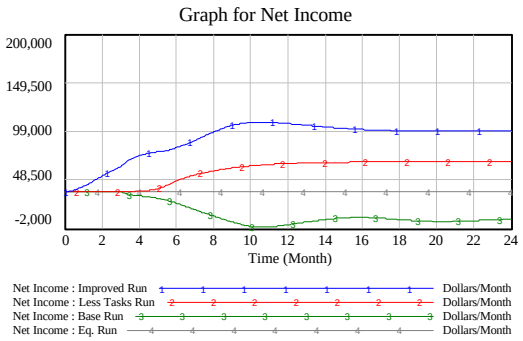

Figure 25—Net Income (Comparative)

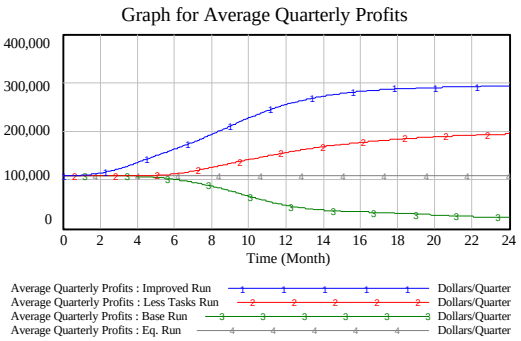

Figure 26—Quarterly Profits (Comparative)

When combined changes are simulated, the system's improvement is significant with respect to an, also significant, previous improvement in workload ratio and profits. Average quarterly profits increase by 50% with respect to the next best run. These simulated results were considered by the group as very important to explore further to understand better the structural relationships present that created the possibility of these results. After discussing about these results, the group generated momentum policies for the system.

The Momentum Policies Generated

The group, analyzing the simulation results, proposed the exploration of policies to change the behavior of the system. The policies are:

1. Training programs for all levels of employees
2. Cross training in multiple skills
3. Specializing individuals in the practice
4. Standardization of processes
5. Hire right candidates (changing the hiring policy)
6. Strictly enforce Customer service policies
7. Get involved in community service
8. Keep an organizational 'low profile' to avoid jealousy
9. Slow down the pace of the practice

The Recognized Insights

The modeling process allowed the group to recognize insights about the customers, workload, innovations, net earnings, and jealously. The insights are:

- Customers
  - Dissatisfied patients affect the practice more than the satisfied patients
  - The dissatisfied customers increase as the practice grows
  - Just customer satisfaction is not enough, delighting the customers is important
  - Participating with insurance plans could lead to exposure in the community and opportunity for good will development

- Work Load
  - Work Load on Staff initially increases productivity and when the stress increases, the productivity drops
  - The Work Load affects the perceived quality of care that results in bad word of mouth
  - As the practice sees more patients, more revenues allows hiring more staff to reduce the work load
- Innovations
  - The innovations in quality initiatives will be very important to maintain the cost savings and reputation
  - Lean Systems would reduce the number of tasks per patients and improve productivity
- Net Earning
  - The part of net earning attributed to training of the staff will reduce the work load and increase productivity
  - The shorter the time to train people, more rapidly workload will be distributed, more productive the staff will be, and more profitable the organization will become
  - Increasing the fraction of higher-paying patients will increase the net earnings
- Jealousy
  - Jealousy can lead to Bad of Word of Mouth and other actions

The Recommended Policies

After analyzing the simulation results and the effects of different policies on the behavior of the system, the group decided on certain policies to be recommended to management for implementation. The policies are:

- Human Resources
  - Balance Work Load and Maintain optimum Work Load Ratio to stimulate productivity
  - Hire the best and highly specialized staff to ensure the productive staff is working on taking care of patients
- Innovations Implementation
  - Implement Lean and Quality six sigma initiatives, it would reduce number of tasks required per patient, thus improve cycle time of treatment and improve the quality of patient care
  - Hire the best and highly specialized staff or consultants to ensure the productive staff is working on taking care of patients while innovation implementations
- Market
  - Increase participation of referring doctors who send higher-end patients

Final Comments

Innovation implementation in organizations deals at its core with systematic beliefs that create a psychological interplay between order and chaos in the organization (Goertzel, 1994). In other words, the implementation of innovations has more to do with *how* we do it than with *what* we do in organizations. Management has a central role in the process of generating successful implementations of innovations. As Stata (1992) creatively articulates, ‘usually, innovation is though in terms of technologies that give rise to new products or improvements in existing

products. However, product and process innovation is not the primary bottleneck to progress. The bottleneck is management.'

The development of the model generated an increase in the employee awareness of their individual impact in the organization, an overall assessment that general impact has been captured in the model, and a preliminary understanding of the dynamics of innovation implementation in the firm. However, the managing team still thinks that the interconnectedness of the system is not yet clear for everyone and that a shared vision of the structure and purpose of the practice should be reinforced.

What to explore in the future? The group has expressed an interest in exploring both the scope and detail of the model as well as ground it with data from the practice, both quantitative and qualitative. The model can be expanded and adapted into a general model for health care practices, law offices, accounting practices, or other service intensive firms. Continuing the study can lead to an enlarged model including the entire value chain, insurance carriers, general family practitioners, related specialists, suppliers, and laboratories. A different area to explore is to endogenously generate the effects of success in innovation implementation over time; this is to generate transient dynamics that explain the initial success or failure of innovation programs followed by their opposite dynamics. Conventional research always points to the need of early success to create 'momentum' or motivation for change in organizations, however, as has been extensible studied in system dynamics, social systems can exhibit counterintuitive behavior (Forrester, 1975). Probably in cases in which innovation implementation is knowledge-based and is highly dependent in individual interactions to provide services, early success may not always contribute to long term success (for a very interesting exploration of these possibilities see Repenning, 2002).

References

Andersen, D. F. and G. P. Richardson (1997). "Scripts for Group Model Building." System Dynamics Review **13**(2): 107-129.

Andersen, D. F., G. P. Richardson and J. A. M. Vennix (1997). "Group Model Building: Adding More Science to the Craft." System Dynamics Review **13**(2): 187-201.

Argyris, C., R. Putnam and D. M. Smith (1985). Action Science: concepts, methods and skills for research and intervention. San Francisco, California, Jossey-Bass.

Argyris, C. and D. A. Schön (1996). Organizational Learning II: Theory, Method, and Practice. New York, Addison-Wesley Publishing Company.

Brickley, J. A., C. W. Smith and J. L. Zimmerman (2001). Managerial Economics and Organizational Architecture. Boston, MA, McGraw-Hill Irwin.

Cobbenhagen, J. (2000). Successful Innovation. Cheltenham, UK, Edward Elgar.

Forrester, J. W. (1975). Counterintuitive Behavior of Social Systems. Collected Papers of Jay W. Forrester. Cambridge MA, Productivity Press**:** 211-244.

Goertzel, B. (1994). Chaotic Logic: Language, Thought, and Reality from the Perspective of Complex Systems Science. New York, Plenum Press.

Lane, D. C. and R. Oliva (1994). The Greater Whole: Toward a Synthesis of SD and SSM. 1994 International System Dynamics Conference, Sterling, Scotland, System Dynamics Society.

Martinez, I. J. and G. P. Richardson (2001). Best Practices in System Dynamics Modeling. Proceedings of the 19th International Conference of the System Dynamics Society, Atlanta, GA USA, System Dynamics Society.

Milling, P. M. (2002). "Understanding and Managing Innovation Procesess." System Dynamics Review **18**(1): 73-86.

Repenning, N. (2002). "A Simulation-Based Approach to Understanding the Dynamics of Innovation Implementation." Organization Science **13**(2): 109-127.

Richardson, G. P. (1991). Feedback Thought in Social Science and Systems Theory. Waltham, MA, Pegasus Communications.

Stata, R. (1992). "Management Innovation." Executive Excellence **9**(6): 8-9.

Sterman, J. D. (2000). Business Dynamics: Systems Thinking and Modeling for a Complex World. Boston MA, Irwin McGraw-Hill.

Wilensky, H. L. (1967). Organizational Intelligence: Knowledge and Policy in Government and Industry. New York, Basic Books, Inc., Publishers.

Equations of the Model

```
**********************************
   V1 1
**********************************
```

(002) "$/Patient High"=900
Units: Dollars/Patients
(003) "$/patient Low"=350
Units: Dollars/Patients
(004) "$/Patient Medium"=550
Units: Dollars/Patients
(005) Additions to Cumulative Patients=Outflow rate
Units: Patients/Month
(006) Adjustment time for moving staff=2
Units: Month
(007) Adjustment Time for Perception of Quality=1
Units: Month
(008) Adjustment Time for Quarterly Profits=6
Units: Month
(009) Average Out patient per group=Outflow rate
Units: Patients/Month
(010) "Average patients referred/month/referring people"=3
Units: Patients/Month/Referring people
(011) Average Quarterly Profits= INTEG (Net Change in Quarterly Profits, Estimated Quarterly Profits)
Units: Dollars/Quarter
(012) "Average Tasks/patient"="Average Tasks/patient Normal"*(1+STEP(Step in tasks, Time to step in tasks))
Units: Tasks/Patients
(013) "Average Tasks/patient Normal"=10
Units: Tasks/Patients
(014) "Average time to get experience/staff"=1
Units: Month
(015) Average Training per employee=Level Of Training/Total Staff
Units: Learning/Staff
(016) "Avg. Backlog to tasks"=Backlog of Patients/Tasks
Units: Patients/Tasks
(017) "Avg. Salary per staff per month"=4000
Units: Dollars/Month/Staff
(018) Backlog of Patients= INTEG (Inflow rate-Outflow rate,330)
Units: Patients
(019) Completion rate=Productivity*Total Productive Staff
Units: Tasks/Month
(020) Cumulative Patients= INTEG (Additions to Cumulative Patients,0)
Units: Patients
(021) Current Contact Per Month="Normal Contacts with People/Month"*Effect of the Workload Ratio on Marketing
Units: Referring people/Month
(022) Current Fraction of High patients=Desired Fraction of High patients/Total Fraction
Units: Dmnl
(023) Current Fraction of Low patients=Desired Fraction of Low patients/Total Fraction
Units: Dmnl
(024) Current Fraction of Medium patients=Desired Fraction of Medium patients/Total Fraction
Units: Dmnl
(025) Current Quality of Services=Effect of WorkLoad Ratio on Quality*Quality of Services normal

Units: Quality
(026) Desired Fraction of High patients=1/3
Units: Dmnl
(027) Desired Fraction of Low patients=1/3
Units: Dmnl
(028) Desired Fraction of Medium patients=1/3
Units: Dmnl
(029) Desired Staff=28
Units: Staff
(030) Desired training level=30
Units: Learning/Staff
(031) Effect of Reputation on Loss of referral=f Effect of Reputation on Loss of referral(Reputation)
Units: Dmnl
(032) Effect of Reputation on new referrals=f Effect of Reputation on new referrals(Reputation)
Units: Dmnl
(033) Effect of the Workload Ratio on Marketing=f Effect of the Workload Ratio on Marketing(WorkLoad Ratio)
Units: Dmnl
(034) Effect of WorkLoad onProductivity=f Effect of WorkLoad onProductivity(WorkLoad Ratio)
Units: Dmnl
(035) Effect of WorkLoad Ratio on Quality=f Effect of WorkLoad Ratio on Quality(WorkLoad Ratio)
Units: Dmnl
(036) Estimated Quarterly Profits=Months Per Quarter*Net Income
Units: Dollars/Quarter
(037) Experienced Staff= INTEG ((Gaining experience-Quitting)-Staff moving to training functions,28)
Units: Staff
(038) "Experienced Staff (Training)"= INTEG (Staff moving to training functions,0)
Units: Staff
(039) f Effect of Reputation on Loss of referral([(0,0),(2,2)],(0,2),(0.293578,1.84211),(0.617737,1.75439),(0.776758,1.68421),(0.954128,1.47368),(1,1),(1.11927,0.631579),(1.22936,0.45614),(1.45566,0.254386),(1.68196,0.166667),(2,0.1))
Units: Dmnl
(040) f Effect of Reputation on new referrals([(0,0)-(2,2)],(0,0),(0.238532,0.45614),(0.605505,0.807018),(1,1),(1.33945,1.2807),(2,1.5))
Units: Dmnl
(041) f Effect of the Workload Ratio on Marketing([(0,0)-(2,40)],(0,30),(0.0733945,29.4737),(0.140673,27.7193),(0.238532,25.4386),(0.35474,21.5789),(0.593272,10.513),(0.850153,1.10526),(1,1),(2,1))
Units: Dmnl
(042) f Effect of WorkLoad onProductivity([(0,0)-(2,2)],(0,0),(1,1),(1.27829,1.20175),(1.4,1.2),(1.6,0.947368),(1.78593,0.710526),(2,0.5))
Units: Dmnl
(043) f Effect of WorkLoad Ratio on Quality([(0,0)-(2,2)],(0,1.2),(0.2,1.2),(0.4,1.17),(0.6,1.12),(0.8,1.06),(1,1),(1.2,0.8736),(1.4,0.712),(1.6,0.489),(1.8,0.3),(2,0.15))
Units: Dmnl
(044) f pressure to increase training staff([(0,0)-(2,0.1)],(0,0.02),(0.256881,0.0157895),(0.391437,0.0122807),(0.556575,0.00701754),(0.715596,0),(1,0),(2,0))
Units: Dmnl
(045) f Pressure to Reduce Staff([(0,0)-(2,1)],(0,0.2),(1,0.75),(2,1))
Units: Dmnl
(046) f Pressure to reduce training staff([(0,0)-(2,1)],(0,0),(1,0),(2,1))
Units: Dmnl
(047) Fraction Experienced Staff Desired in Training=0.2

Units: Dmnl
(048) Fraction of Experienced Staff in Training="Experienced Staff (Training)"/Total Experienced Staff
Units: Dmnl
(049) "Fraction of referring base loss/month"=0.1
Units: Dmnl/Month
(050) Fraction patient High=Patients High/Total Patients
Units: Dmnl
(051) Fraction patient low=Patients Low/Total Patients
Units: Dmnl
(052) Fraction patient Medium=Patients Medium/Total Patients
Units: Dmnl
(053) Gaining experience=Inexperienced Staff/"Average time to get experience/staff"
Units: Staff/Month
(054) Gaining New referrals=Effect of Reputation on new referrals*Current Contact Per Month
Units: Referring people/Month
(055) In patient High=Current Fraction of High patients*New referred patients
Units: Patients/Month
(056) In Patients low=Current Fraction of Low patients*New referred patients
Units: Patients/Month
(057) In Patients Medium=Current Fraction of Medium patients*New referred patients
Units: Patients/Month
(058) Incoming task=Inflow rate*"Average Tasks/patient"
Units: Tasks/Month
(059) Increase in training benefits=Staff Learning
Units: Learning/Month
(060) Increase Staff Providing Training=Staff moved to training*pressure to increase training staff
Units: Staff/Month
(061) Inexperienced Staff= INTEG ((+New hiring rate-Gaining experience),0)
Units: Staff
(062) Inflow rate=Total Patients in
Units: Patients/Month
(063) Length of Employment=50
Units: Month
(064) Level Of Training= INTEG (Increase in training benefits-Training benefits lost when staff leaves,1677)
Units: Learning
(065) Loss of referral=Effect of Reputation on Loss of referral*"Fraction of referring base loss/month" *Referring Base
Units: Referring people/Month
(066) Minimum Required Quarterly Profits=1000
Units: Dollars/Quarter
(067) Months Per Quarter=3
Units: Months/Quarter
(068) Net Change in Quarterly Profits=(Estimated Quarterly Profits-Average Quarterly Profits)/Adjustment Time for Quarterly Profits
Units: Dollars/Quarter/Month
(069) Net Income=Total Revenue-Total staff Cost-Other Cost
Units: Dollars/Month
(070) New hiring rate=Quitting*Pressure to Reduce Staff
Units: Staff/Month
(071) New referred patients=Referring Base*"Average patients referred/month/referring people"
Units: Patients/Month
(072) "Normal Contacts with People/Month"=22
Units: Referring people/Month
(073) Normal WorkLoad=118
Units: Tasks/Staff

(074) Other Cost=50000
Units: Dollars/Month
(075) Out Patient High=Average Out patient per group*Fraction patient High
Units: Patients/Month
(076) Out Patient low=Average Out patient per group*Fraction patient low
Units: Patients/Month
(077) Out patient Medium=Average Out patient per group*Fraction patient Medium
Units: Patients/Month
(078) Outflow rate=Completion rate*"Avg. Backlog to tasks"
Units: Patients/Month
(079) Patients High= INTEG (In patient High-Out Patient High,110)
Units: Patients
(080) Patients Low= INTEG (In Patients low-Out Patient low,110)
Units: Patients
(081) Patients Medium= INTEG (In Patients Medium-Out patient Medium,110)
Units: Patients
(082) Perception of Quality=SMOOTH(Current Quality of Services, Adjustment Time for Perception of Quality)
Units: Quality
(083) pressure to increase training staff=f pressure to increase training staff(Ratio of Avg to Desired level of training)
Units: Dmnl
(084) Pressure to Reduce Staff=f Pressure to Reduce Staff(Ratio of Average Quarterly Profits to Min Reqd)
Units: Dmnl
(085) Pressure to reduce training staff=f Pressure to reduce training staff(Ratio of Avg to Desired level of training)
Units: Dmnl
(086) Productivity=Productivity Normal*Effect of WorkLoad onProductivity
Units: (Tasks/Staff)/Month
(087) Productivity Normal=118
Units: (Tasks/Staff)/Month
(088) Quality of Services normal=1
Units: Quality
(089) Quitting=Experienced Staff/(Length of Employment*Pressure to Reduce Staff)
Units: Staff/Month
(090) Ratio of Average Quarterly Profits to Min Reqd=Average Quarterly Profits/Minimum Required Quarterly Profits
Units: Dmnl
(091) Ratio of Avg to Desired level of training=Average Training per employee/Desired training level
Units: Dmnl
(092) Ratio of Perceived Quality to Normal Quality=Perception of Quality/Quality of Services normal
Units: Dmnl
(093) Reduction in staff training="Experienced Staff (Training)"*Pressure to reduce training staff/Adjustment time for moving staff
Units: Staff/Month
(094) Referring Base= INTEG (+Gaining New referrals-Loss of referral,110)
Units: Referring people
(095) Reputation=Ratio of Perceived Quality to Normal Quality
Units: Dmnl
(096) Staff Learning=("Experienced Staff (Training)"*Trainer training Productivity)/Time for Learning to sink in
Units: Learning/Month
(097) Staff moved to training=Experienced Staff*(Fraction Experienced Staff Desired in Training-Fraction of Experienced Staff in Training)/Adjustment time for moving staff
Units: Staff/Month

(098) Staff moving to training functions=-Reduction in staff training+Increase Staff Providing Training
Units: Staff/Month
(099) Staff to hire=Desired Staff-Total Staff
Units: Staff
(100) Step in tasks=-0.2
Units: Dmnl
(101) Tasks= INTEG (+Incoming task-Completion rate,3300)
Units: Tasks
(102) Time for Learning to sink in=2
Units: Month
(103) Time to hire=1
Units: Month
(104) Time to step in tasks=3
Units: Month
(105) Total Experienced Staff="Experienced Staff (Training)"+Experienced Staff
Units: Staff
(106) Total Fraction=Desired Fraction of High patients+Desired Fraction of Low patients+Desired Fraction of Medium patients
Units: Dmnl
(107) Total Patients=Patients High+Patients Low+Patients Medium
Units: Patients
(108) Total Patients in=In patient High+In Patients low+In Patients Medium
Units: Patients/Month
(109) Total Productive Staff=Experienced Staff+Inexperienced Staff
Units: Staff
(110) Total Revenue="Total Revenue/Month from High"+"Total Revenue/month from Low"+"Total Revenue/Month from Medium"
Units: Dollars/Month
(111) "Total Revenue/Month from High"="$/Patient High"*Out Patient High
Units: Dollars/Month
(112) "Total Revenue/month from Low"="$/patient Low"*Out Patient low
Units: Dollars/Month
(113) "Total Revenue/Month from Medium"="$/Patient Medium"*Out patient Medium
Units: Dollars/Month
(114) Total Staff="Experienced Staff (Training)"+Total Productive Staff
Units: Staff
(115) Total staff Cost=Total Staff*"Avg. Salary per staff per month"
Units: Dollars/Month
(116) Trainer training Productivity=10
Units: Learning/Staff
(117) Training benefits lost when staff leaves=0
Units: Learning/Month
(118) WorkLoad=Tasks/Total Productive Staff
Units: Tasks/Staff
(119) WorkLoad Ratio=WorkLoad/Normal WorkLoad
Units: Dmnl

****
.Control
****
Simulation Control Parameters

(121) FINAL TIME = 24
Units: Month
(122) INITIAL TIME = 0
Units: Month

(123) SAVEPER = TIME STEP
Units: Month [0,?]
(124) TIME STEP = 0.0625
Units: Month [0,?]

Back to the Top