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System Dynamics And Nursing Lines: Cost Saving Measures at Eastern Connecticut Healthcare Network

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System Dynamics and Nursing Lines: Cost Saving Measures at ECHN

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Abstract

The project addresses problems associated with usage and cost of disposable medical supplies on a nursing line. As hospitals look for methods to reduce costs without cutting performance or patient satisfaction, supply line inefficiencies are coming under heavy scrutiny. Working with representatives from a non-profit group, Eastern Connecticut Health Network, a major supply problem was identified and a system dynamics model was created in Vensim for a particular nursing line. The resultant model indicates that a lack of observable feedback and response has placed ECHN into a position where uncharged disposable medical supplies increase costs. It was concluded that based on current conditions, increasing disposable medical supply value awareness would create a net savings for the hospital.

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Executive Summary

Non-profit hospitals must balance their duty to provide optimal care for their patients and their ability to finance their operations. Due to the rising costs of healthcare in the United States, non-profit health systems like the Eastern Connecticut Healthcare Network (ECHN) are always looking for methods to reduce their overhead costs and find savings that do not hurt patient care. Cost reduction techniques range from improved information system databases which allow for greater supply chain control to implementation of alternative care systems such as therapeutic pets. Yet many hospitals can find much simpler ways to increase their bottom line if they look at their basic operations.

Today many hospitals are conducting expensive studies or capital intensive system upgrades as strategies to reduce costs. This can result in cheaper methods of cost reduction being overlooked. A focus on technology and methodology can mask underlying problems. Neglecting personnel issues and basic problems on the hospital floor can potentially create a costly or ineffective solution[1]. Hindering the assessment of small problems on the hospital floor is the fact that their results are often difficult to predict; data is not necessarily collected on the human factor involved in these minor changes nor is it quantified in a usable context. In an era where economic pressures have reduced the viability of making capital investments, such small changes are gaining additional support and are more likely to be used[2].

[1] (Rose, 2008)
[2] (What's ailing health care?, 2009, p.1)

The project's goal was to work with representatives from a local area non-profit health network on finding ways to reduce hospital costs. Rather than attempting to address a wide variety of issues in the hospital, the system dynamics methodology implemented focused on narrowing down concerns to a single item. Working with members of the ECHN staff during the first term of the project, it was identified that disposable supplies on the floor of various medical nursing units were being used at a greater rate than predicted at significant cost to the hospital. This issue is further compounded by the hospital's need to maintain patient satisfaction and limited resources for capital investment into new equipment or training methods.

The initial theory identifies three main supply line issues:

1. Nurses are using supplies as shortcut methods to spend more time with patients, especially if busy.
2. Nurses are not charging patients for supplies.
3. Too many supplies were being used as an overtreatment of individual patients.

The model was designed to look at the long term repercussions of these negative behaviors and how ECHN could employ effective countermeasures at the target hospital. The models currently available in literature focus strictly on the actual supply chains themselves and how inventories are maintained, rather than what dictates demand for various items over base medical needs. Such models posse limited usefulness as many of the supply line issues present at ECHN are not from inventory control but derive from choices made by the nurses as primary providers. A model which explicitly considers factors such as: failure to charge rate;

overtreatment rate; shortcut usage; and nurse reaction to management pressures or educational efforts can create feedbacks which will illustrate a better way to analyze methods on reducing supply costs.

In order to create the model, causal loops were established by working closely in a feedback intensive environment with ECHN representatives. The model's purpose is to create an underlying structure that can be adapted to meet ECHN's specific policy needs and their reactions thus far. ECHN has historically had difficulty with over usage and undercharging of supplies and has only recently chosen to address this issue. The relationship between demand, supply, satisfaction, education, and price was developed and reviewed with proper tests. The model was developed using the system dynamics software, Vensim.

Three scenarios were proposed to predict the change in supply usage for the different combinations of how nursing price awareness and nursing psychological safety affected the three main areas of disposable supply loss: failure to charge, over usage, and patient satisfaction. The models also highlight ECHN's lack of responsive feedback to the current problem. The three scenarios provide the worst, middle-ground, and the best cases possible for ECHN's proposed momentum policies; the best case resulting in the lowest losses on the supply line. The current policies seem to have been enough to stem the worst case; the purpose of the worst case was to provide the upper boundary in the range of improper supply usage and to test the effects of unresponsive nursing staff. In the developing scenarios, it was determined that part of ECHN's problem stemmed from the fact that its current system lacked responsive

feedback; changes were not heavily promoted during good economic times as a way to stem problems.

Two additional scenarios were developed for the model. In the first scenario, options involving capital investment for changing controls on the supply chain were added. This scenario reflects the idea that ECHN raised enough short term capital for the long term improvement, with the hope that more detailed inventory controls could be used to identify misappropriated supplies and create individual awareness and accountability. The second scenario examines what would happen if certain nursing supply shortcuts were adopted as standard operating procedures so that these supplies could be charged to the patient.

The scenarios developed for this model are based on an individual hospital line at ECHN. This model could be used with data from other hospitals to provide insights and policy recommendations. Important to any customization or modification of the model would be the fact that feedback was built around ECHN's current, but not necessarily optimal, systems..

The results from these scenarios are not the ultimate answers to optimizing nursing disposable supply usage. Additional data should be gathered reflecting the nurses' responses to policy changes, and also the exact effects such policies have on the hospital's reputation and patient satisfaction. The additional long term costs of the policy recommendations implemented in some scenarios are not immediately clear. Especially problematic is the fact that the base cost of medical supplies has been historically increasing. So even in the best

scenario an unwanted expense increase would occur for the hospital[3]. Based on all of these factors a number of viable policies were developed.

[3] (Rose, 2008)

Chapter 1: Introduction and Background

1.1Introduction

Hospitals, or a form of them, have been around since 4000 BC; often as an extension of religion or military power[4]. These early hospitals were primary religiously driven and hospitals resembling today's medical centers did not come about as dedicated treatment centers until later in the medieval ages[5]. The modern American non-profit medical hospital grew out of alms houses and did not exist in a form similar to modern public health models until the 1800s[6]. Now non-profit hospitals are the largest portion of the US hospital system with almost 2900 active hospitals[7]. These hospitals admit millions of US citizens every year and many cannot turn away a patient due to their charters[8]. Unfortunately, the cost of these various patient treatments clash with the hospitals non-profit natures.

Non-profit hospitals play a critical role in the United States healthcare system due to their universal coverage. They also have to deal with tremendous costs in their operations. Starting in 1985 medical items have gone up in price significantly faster than the rest of the consumer price index and show no slowing in rate of increase (see Table 1).

[4] (Hospital. International ed., 2008)
[5] (Hospital. International ed., 2008)
[6] (Patel & Rushefsky, 2006, p.35)
[7] (Fast facts on US hospitals, 2009)
[8] (Patel & Rushefsky, 2006, p.37)

	All items	Medical Items
1960	29.6	22.3
1965	31.5	25.2
1970	38.8	34.0
1975	53.8	47.5
1980	82.4	74.9
1985	107.6	113.5
1990	130.7	162.8
2000	152.4	220.5
2000	172.2	260.8
2001	177.1	272.8
2002	179.9	286.8

Table 1: Consumer Price Index, 1960-2002[9]

The enormous cost of medical items in the United States has put undue financial strain on many hospitals, forcing them to figure out how they can run leaner while ensuring their patients' right to care[10]. The present financial burdens have been developing since the 1980s when there were concerns about hospitals' ability to finance capital improvements[11]. Hospitals employ a variety of fundraising techniques to combat their deficits and supplement the income lost from unpaid hospital bills, but the uphill struggle to find financing is reaching a crisis point in many areas. In the southern portion of the United States, 10% of rural hospitals have shut down since the 1980s[12]. The loss of the services provided by these hospitals is widely felt in the areas they left behind where many people are denied access to needed healthcare[13]. Problems such as these have only gotten worse due to the recent economic fluctuations.

The economic recession, beginning in late 2008, has turned many hospital financial board meetings into a fight for survival. Decreasing privately insured patient volumes, Medicaid reimbursement reductions, and other lost sources of revenue have forced hospitals to

[9] (Patel & Rushefsky, 2006, p.53)
[10] (Newhouse, 1970, p.64)
[11] (Cohedes, 1983, p.64)
[12] (Reif, DesHarnais, & Bernard, 1999, p.202)
[13] (Reif et al., 1999, p.206)

make painful cuts[14]. Many hospitals find their loans to be 15% higher than a year ago and their long term investments providing smaller returns[15]. This crisis has highlighted the problems many non-profit organizations, not just hospitals, face in their quest for sustainable services. However, this recession provides new opportunities for hospitals to grow and become stronger[16].

As long as non-profit American hospitals have existed, cost trimming research has been performed. Thanks to evolving technology, the latest trend is using Information Systems to gather more detailed data about hospital infrastructure to determine areas requiring improvement[17]. Such data identifies one of the most effective financial strategies is a renewed focus on managing direct costs for patient treatment[18]. Reducing costs at this level does not necessarily consist of reducing patient care, and by extension patient satisfaction, but instead requires hospitals to reevaluate their current procedures and policies; they must look for inefficiencies inherent in their system. In many cases, changes to these areas can be done with lower capital investments than are required for larger restructuring projects, yet they still create a noticeable effect on the hospitals bottom line.[19].

ECHN has specifically identified cost overruns in disposable medical supplies as one area for potential savings. A single nursing line at Manchester Memorial Hospital was selected for this study. Though in a sound financial position, the organization has made workforce

[14] (Bush, 2009a, p.41-42)
[15] (Bush, 2009b, p.24)
[16] (Bush, 2009b, p.26)
[17] (Botz, Sutherland, & Lawrenson, 2006, p.111)
[18] (Pizzini, 2006, p.204)
[19] (Newhouse, 1970, p.65)

reductions and other sacrifices to maintain financial stability over the past year. Continuing to plan ahead, ECHN hopes to figure out methods for reducing extraneous supply usage on the nursing supply lines and become a more streamlined organization. Also, the goal is to approach the methodology with a higher focus on the less capital intensive human elements of the model rather than an Information System based solution.

Using the insights of previous research, including Hospital Nurse Productivity Enhancement by Steven Eastaugh and the research of Anita Tucker into why hospitals fail to adapt, the project's goal is to provide a conclusive set of solutions and supporting data which will allow ECHN to address the disposable medical supply line problem. One of the greatest limitations for the project is ECHN's inability to make capital improvements to the supply line itself, a technique other organizations have employed in the past[20]. Instead, this approach will look at feedback loops between nurses, their choices in using supplies, and their interaction with patients to create a robust and realistic representation of the human side of the system that explains the over usage of supplies. A system dynamics model should be able to coordinate the interrelations among the variables presented. The model will also evaluate ECHN's current feedback system to see if ECHN is presented with the proper information it needs.

1.2 Background

Structurally, the Manchester Memorial Hospital (MMH) nursing unit supply lines are built around patient needs first and hospital needs second. Each nursing unit has their own supply closet and a corresponding budget allotment. The close proximity of a fully stocked

[20] (Botz, Sutherland, & Lawrenson, 2006, p.114)

supply closet to each nursing line ensures nurses and doctors can quickly attend to patient needs. A main supply center acts as a distribution point for the individual supply closet; as a closet runs low on stock, the main supply center is contacted and replenishes supplies. Given the speed at which this replenishment typically occurs, there are very few oscillations in the supply chain over a large time scale. The amount of supplies given to each nursing line is tracked and compared to their allotted budget and patient charges. Budgets are determined from historical trends, patient numbers, and patient acuity. Though nursing managers may be reprimanded for it, nursing lines can and often do go over budget. Since their first priority is patient care, a nursing line will never be denied supplies as long as they are available to the hospital.

While some supplies on the line are free for the patient, none of the disposable medical supplies are free for the hospital. Items which patients are charged for have small stickers on them which are left on the patient's medical paperwork. If these stickers are not placed, then the hospital is not able to charge the patient for the cost of the used supply; the value of these supplies is lost and must be deducted from the nursing line budget. Also, any disposable medical supplies taken into a room are considered automatically used but are not automatically charged for sanitary and regulatory reasons. These factors, failure to charge and over treatment, create a deficit in the medical supply budget. Additionally, in order to cope with the fast pace of their jobs while ensuring they have sufficient time to spend with individual patients, interviewed nurses at ECHN have adopted the habit of using medical supplies improperly for shortcuts, especially when there is a significant proportion of high patient acuity per nurse on the nursing floor.

Supply allocation for each nursing line also changes based on the number of patients in the line and their base acuity. A nursing unit with full beds and resource intensive cases will be given more supplies to work with than one without.[21] Nurses themselves have little influence on how these supplies are budgeted yet they are the primary caregivers and likely the best targets to influence costs without significant capital investment[22]. Nurses themselves are also heavily trained on patient care, more so than business end of their jobs, and are not always aware of the additional costs incurred by their shortcuts and supply usage.[23]. Also, various supplies have differing value which causes certain lost supplies to have a higher financial impact than others, a problematic calculation with hundreds of different medical supplies.

Studies indicate a correlation between patient happiness and hospital finances[24]. A poorly financed hospital is more likely to develop a poor reputation and lose the ability to attract patients who can afford to pay the bill and choose the best care. Quality of patient care cannot fall below approximately 70% to 80% for both the comfort of the patients and the reputation of the hospital[25]. As such, small requests from patients for service will continue to be a source of improperly used supplies and the model must account for policy harm in the form of nurses applying shortcuts to keep patients happy. On the other hand, determining how satisfied a patient is based on reductions in overtreatment, shortcut usage, and failure to charge is difficult to quantify. With the failure to charge factor, no patient would want a more expensive hospital bill, but base hospital satisfaction should be good enough without the

[21](Kumar, Ozdamar and Ning Zhang, 2008, p.97)
[22] (Eastaugh, 2007, p.40)
[23] (Eastaugh, 2007, p.41)
[24] (Nelson et al., 1992, p.6)
[25] (Navigating the economic storm: A prescriptive approach for healthcare supply chain professionals, 2008)

benefit of undercharging. A patient may never notice a nurse brought in two bandages instead of the overtreatment of three, but might notice if the nurse rejects an unneeded request for additional bandages.

A final factor considered for the model is the resistance to change on the part of the nursing staff. It is likely the usage of additional supplies on the nursing line is not purposeful but rather habitual. Many nurses are unaware of their inefficient practices and the long term potential impact on hospital finances, creating a problem[26]. Getting hospital personal to adjust and correct these routine errors can be difficult due to three reasons outlined by Anita L. Tucker: "(1) an emphasis on individual vigilance in health care, (2) unit efficiency concerns, and (3) empowerment, or a widely shared goal of developing units that can function without direct managerial assistance.[27]" Though these factors seem beneficial, they can leave nurses feeling overwhelmed and alone if left with a new focus on supply management with adequate training and support[28].

There are two possible leverage points when it comes to influencing the nurses' habits and increasing their awareness of errors. Increasing pressure from management could be implemented by the hospital administration with repercussions for improper supply usage, but such measures often backfire in a human resource situation, where their effect is eventually weakened. A better option may be to use education as a method to increase price awareness for the nurses so they understand the value of the product being lost. Likely the methodology

[26] (Tucker & Edmondson, 2003, p.4)
[27] (Tucker & Edmondson, 2003, p.4)
[28] (Tucker & Edmondson, 2003, p.14)

to determining the loops for this error solving will be adapted from the model presented in Figure 1.

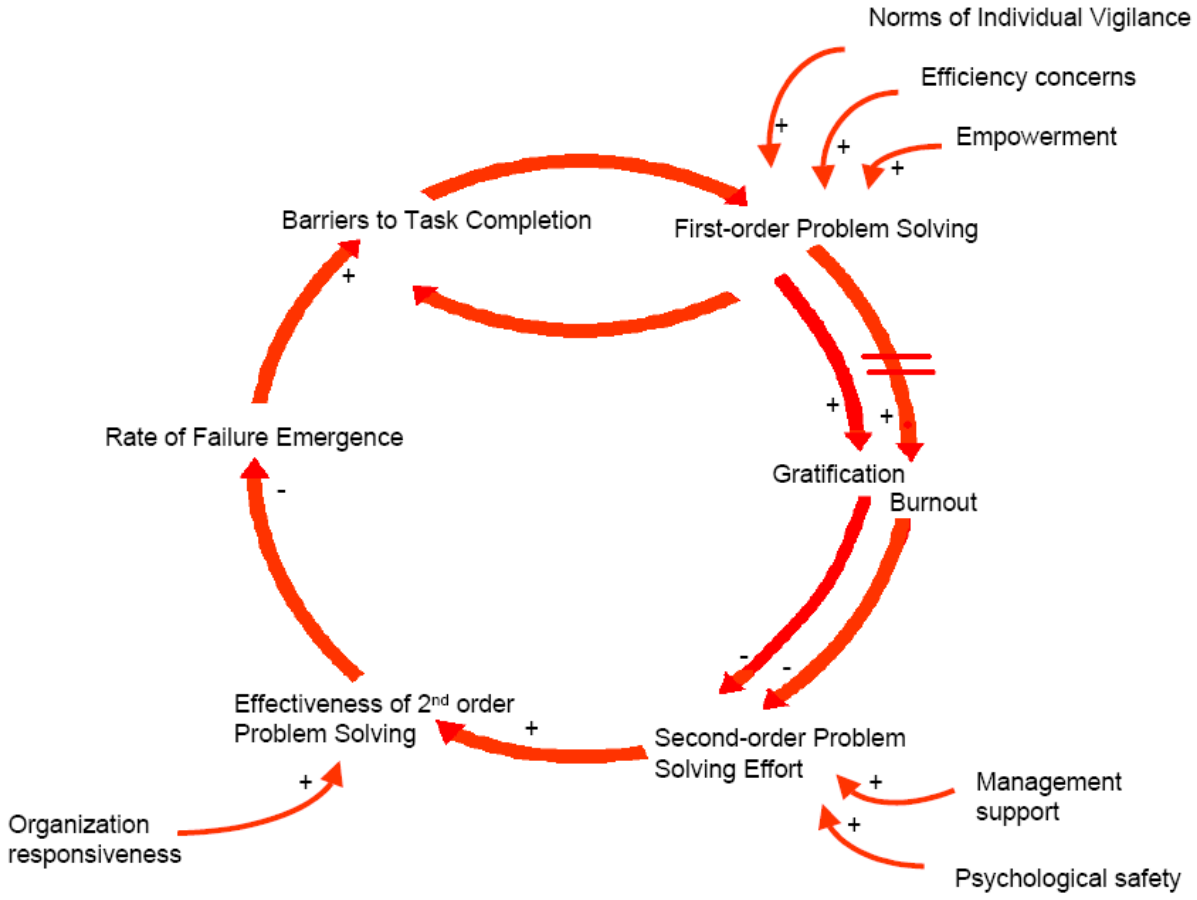

Figure 1: Model of first-order and second-order problem solving behavior [29]

The above model in Figure 1 represents both a first order and second order problem solving loop for a nurse faced with a problem. The diagram is for a singular nurse, rather than a nursing line, but the concepts presented still stand. Depending on day to day pressures, nurses may attempt to solve the problem on their own time if it does not conflict with their work schedule and if they are aware of the problem. Often the 1st order solution is a short term

[29] (Tucker & Edmondson, 2003, p.28)

solution, and it is not until management begins putting additional pressure on nurses that a long term solution is considered. A noticeable difference is in the proposed model ECHN is trying to force nurses to follow policy rather than find their own solution and the structure will likely be closer to the second order portion of the model. Part of the problem with nurses developing their own solutions is that while it may help them in the performance of their jobs it could potentially negatively impact the hospital as a whole. Additionally, many nurses are not aware of the long term costs associated with removing an extra sterile gauze roll from the closet every day.

There have been numerous studies on the individual components of the paper's proposed model, but rarely have the connections between patient happiness, supply usage, and nursing resistance to change been tied together into a single model. A combination of these elements into a singular, custom fit model for ECHN provides an accurate picture of the entire system so that policy recommendations can be made that include all the key elements. Hopefully, the fully formed model can provide ECHN with the data they need to create a more cost effective supply line usage system for their nursing lines.

Chapter 2: Methodology and Analysis

2.1 Consulting Based Model Formulation

The final product for this project is meant to be a functioning model representing the target nursing line and a series of policy insights and recommendations which could be beneficial for ECHN to implement. Rather than build a model from scratch or external data, the model was designed in phases with feedback provided by representatives of ECHN. Through a series of meetings, ECHN team members would be presented with an aspect of the model and their feedback would be recorded. That feedback would create maximum client involvement and allow data to be analyzed and refined by the modeler to meet ECHN's needs. This should create a normalized model that can be easily adapted to ECHN's own nursing line.

2.1.1 Determining Variables

The initial steps of the model building process began with identifying the hospital's wants and needs, specifically which financial issues were of greatest concern. This step was conducted through a series of brainstorming exercises meant to clarify the sponsor's internalized thoughts and instincts. Figuring out common themes of concern was a priority and the process was guided by the modeler to discern why specific variables were being proposed by the sponsor.

From this list (see Appendix A) six key variables were identified; these variables would act as the basis for the model's reference modes. The variables and a brief summary of their reasoning are presented below in Table 2.

Variable	Reasoning
Supply over usage	The recent concern for many hospital administrators was the fact some nursing units were going over budget on their disposable medical supplies. As the price of supplies is not readily controllable to a higher degree than it already is, this will be the main area of focus
Patient Satisfaction	The Hospital's duty is to maintain this at a high level. There is concern that supply usage might be tied to this variable
Nurse hospital policy awareness	Increasing awareness of hospital policies and regulations by the nursing staff regarding supply usage has been one approach to dealing with over usage
Avg. patient acuity per nurse	The ratio of patient acuity to nurses dictates how much a nursing line gets for supplies. It can fluctuate greatly.
Psychological safety	There is concern that nurses who are comfortable with the current system and secure in their position would be resistant to changing their behavior regarding supply usage
Supply Usage as Shortcuts	A main area of perceived over usage is that many supplies are being used improperly by the nurses to save time

Table 2: Key Variables and their Reasoning

2.1.2 Reference Mode Creation and Additional Concerns

The main reference modes of the problem, based on initial work with ECHN, are shown in Table 2. A reference mode is a sketch over time of how a variable behaves. It often has a historical period reflecting what actually happened, and then a range of future possibilities reflecting hopes and fears. These reference modes serve many purposes, such as further establishing the problem and offering a means to compare if the results of the model fit the expected behavior. The reference modes paint a picture of the hospital's perceptions and perceived feedback structure. Each reference mode gives a clear picture of the underlying mechanics of its respective variable in a timescale of months. Each reference mode diverges at around nine months, when the future time paths form. These time paths are the current paths,

feared paths, and hopeful paths respectively. The final references modes do not exactly match up with the selected variables but all are closely related.

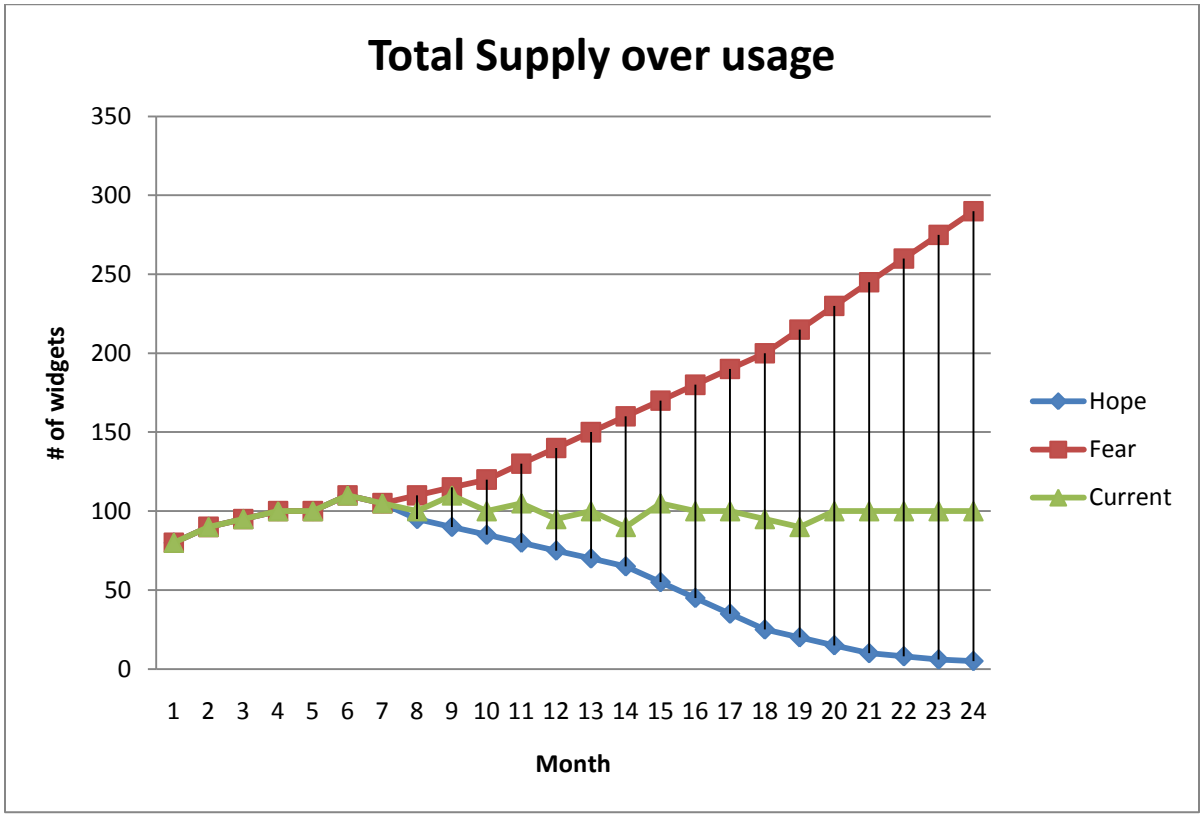

Figure 2: References Mode Supply Over usage

The supply over usage variable has shown a long term trend of slowly increasing over the preferred base usage level. There was discussion about how to handle a significant short term increase in this variable, represented by the fear path. Ideally, this over usage would be as close to a smooth normal usage level as possible. The model is using a smooth normal usage level due to the unpredictability of patient acuity and patient volume, though the final model should have the ability to account for random fluctuations during testing. As such, with smooth normal usage the model will not need patient acuity references.

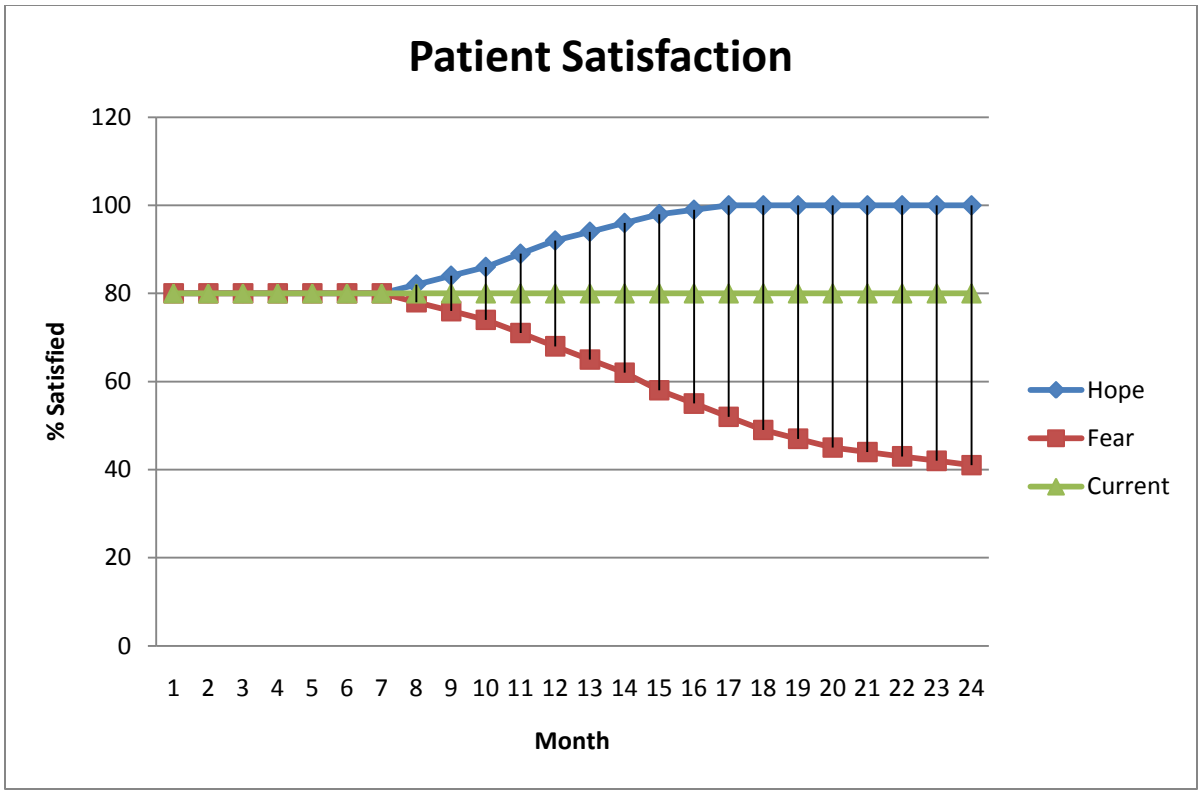

Figure 3 : Patient Satisfaction Reference Mode

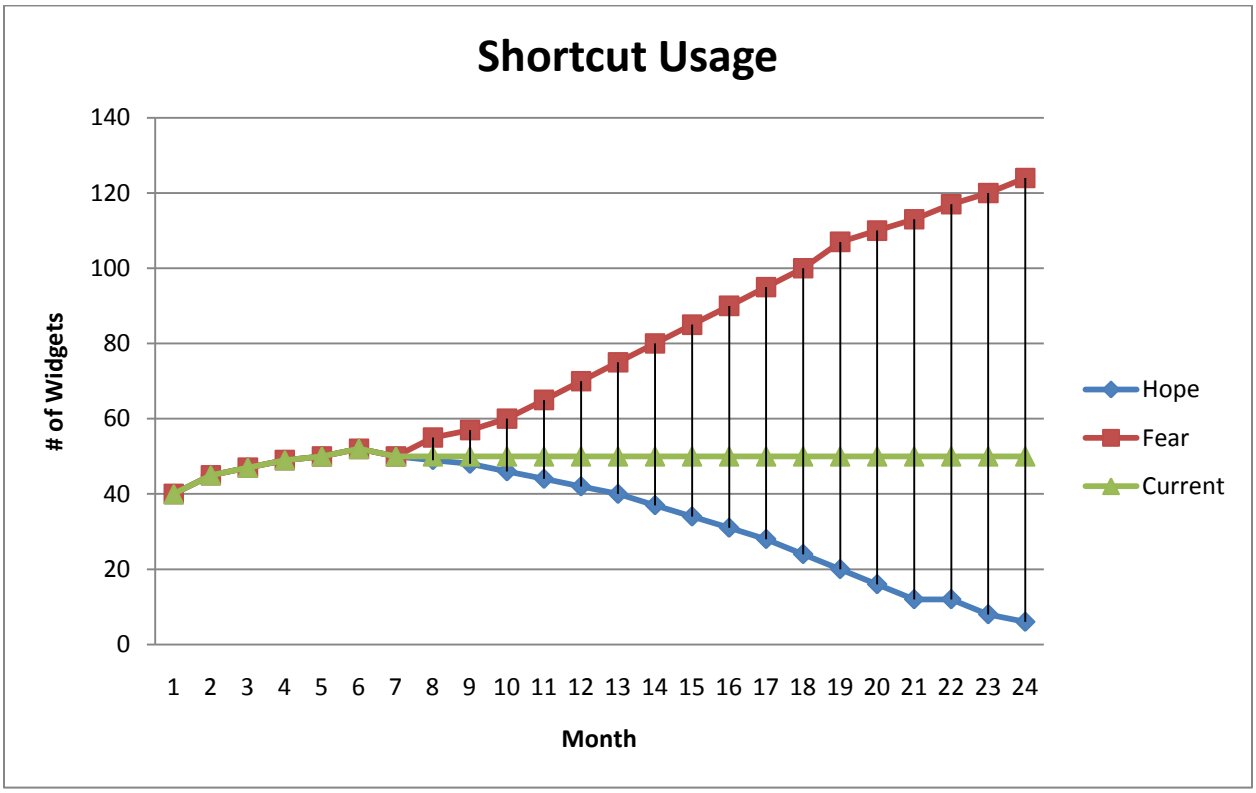

Figure 4: Shortcut Usage Reference Mode

Patient satisfaction at MMH has been held at acceptable levels. The concern is that a new policy to reduce supply usage could cause patient satisfaction to drop. There is always a possibility, however slight, that patient satisfaction could increase. One theory is that lowered patient satisfaction would increase the occurrence of actions such as shortcut usage and overtreatment, hence the similar, but reversed, behavior for the above Figure 3 and Figure 4' fear paths.

The number of nurses, unlike the number of patients or state of acuity, should be relatively constant during the day shift the data is based on. Due to regulations dictating the number and ratio of trained nurses, this amount could not be legally changed as a tool of leverage, as seen in Figure 5.

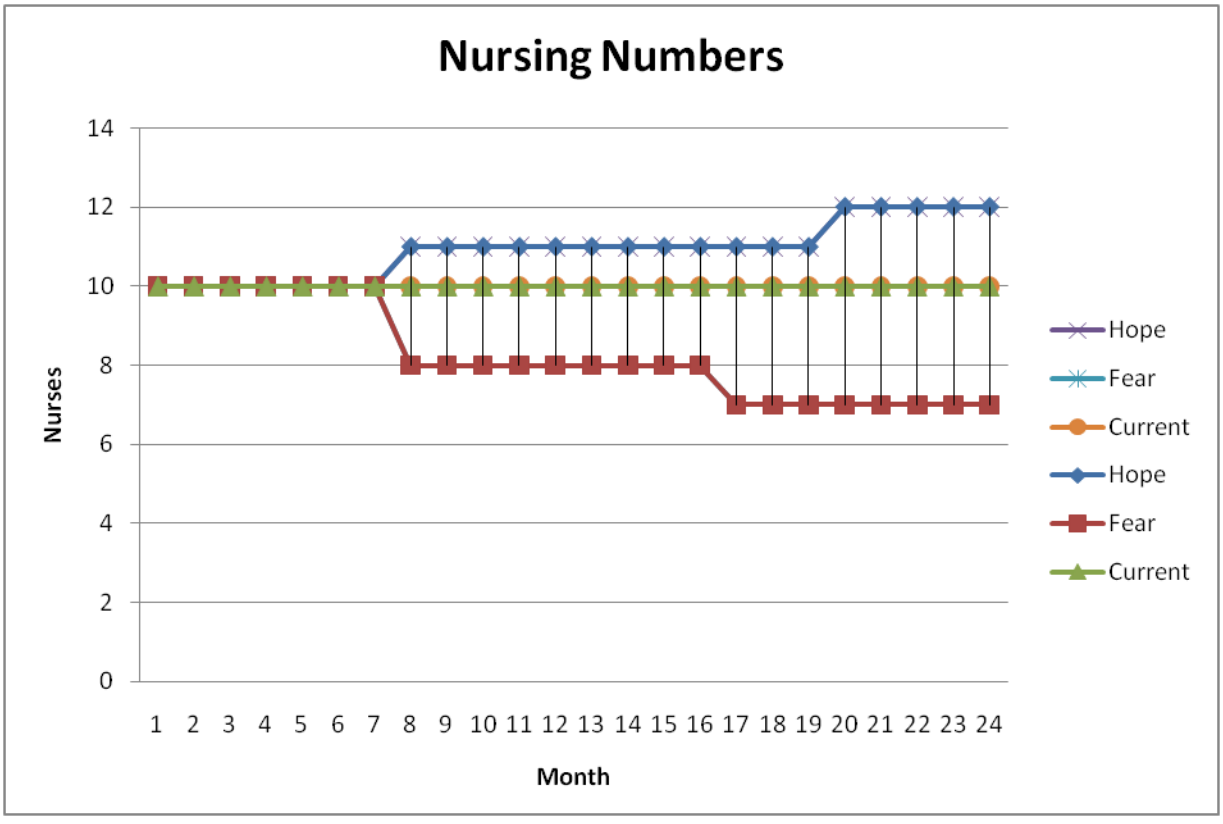

Figure 5: Nurse Numbers Reference Mode

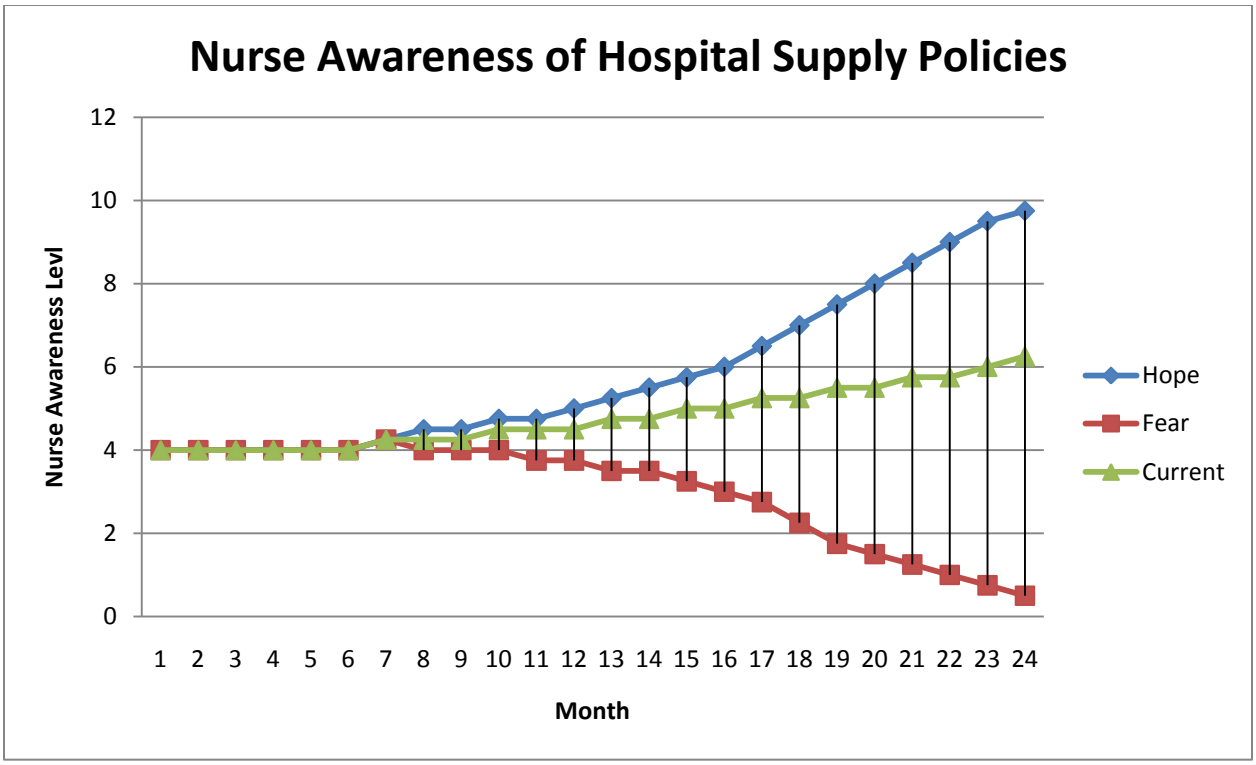

Figure 6: Nurse Supply Cost Awareness

Nurse awareness of policies and regulations is believed to be at a significantly lower than optimum level. ECHN representatives are worried that the level of awareness would continue to be less than optimal or could decrease as veteran nurses trained new staff. there would be a continued decay in hospital policies. A second problem is hiring and firing problem nurses is not easy or cheap. However, a combination of the 2009 recession, recent layoffs and educational efforts around the hospital has made nurses concerned about their job security and their work performance. The above reference modes, as seen later in the first Casual Loop Diagram, seem to lack the necessary feedback to produce some of ECHN's proposed best and worst case scenarios.

2.1.3 Momentum Policies

During discussions with hospital representatives it became apparent that the hospital was already working to correct the supply line issues in two separate ways. The first was to use education, through a major presentation to remind both managers and primary nursing staff, about the value of hospital supplies and proper policies. The second was a more indirect method started by recent layoffs and other cutbacks. People realized that external economic pressures had a real effect on hospital finances. People began taking previously ignored policies more seriously out of a psychological worry.

2.1.4 Problem Statement and Dynamic Hypothesis

Based on the data collected with the sponsor team, the initial problem statement was the following: "ECHN wants to reduce the over usage of disposable medical supplies on the nursing lines without adversely impacting patient care." This problem statement balances the hospital's dual needs of saving money and providing patients with the best possible care.

This problem statement led to the creation of a basic Causal Loop Diagram (CLD) which includes the main highlighted elements of the paper. The CLD depicts the feedback structure believed to be creating the problem behavior in terms of causal links that are either denoted as positive or negative. Negative links mean a variable was established to lower another variable, while a positive variable link increases other variables. Many of these causal links form feedback loops, giving the model its behavior. Feedback loops are either reinforcing or balancing. Reinforcing loops "explode", causing growth, while balancing loops display goal-seeking behavior by trying to reach equilibrium.

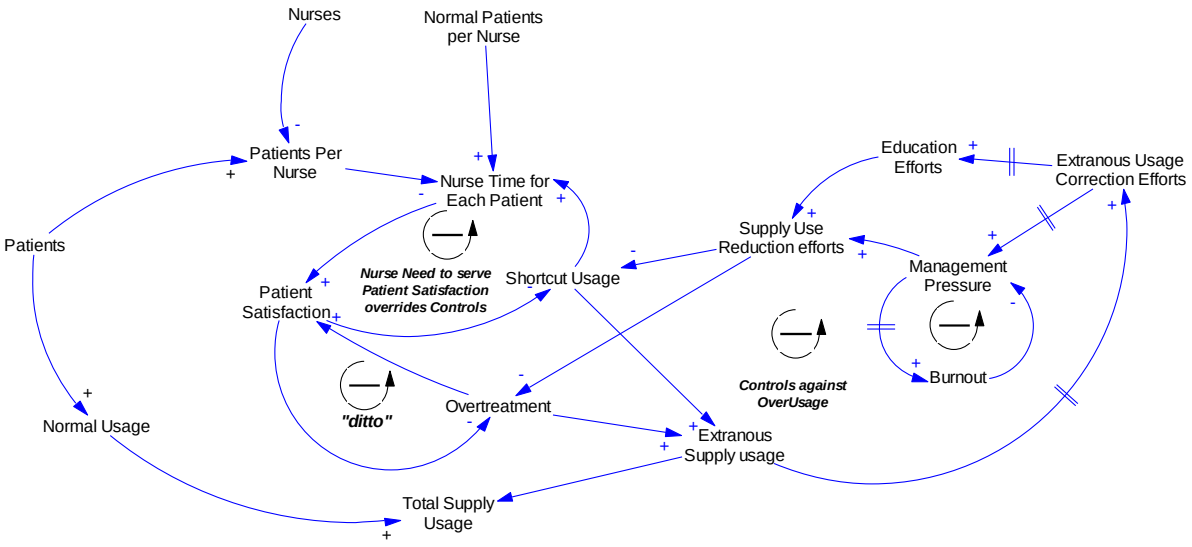

Figure 7: Casual Loop Diagram the First

This CLD represents the key desires and concerns identified at the initial meeting. The goal is that new educational efforts and management pressure will help curb extraneous supply usage. The excessive supply usage comes from over treatment and shortcut usage, which are increased by patient dissatisfaction. Over treatment includes patient requests for additional supplies. Also of concern is that stress, unlike education, has proven itself to be less effective over time. Shortcut usage is used to give nurses more time with each patient so that they can maintain patient satisfaction at a high level despite higher patient loads. Patient load dictates normal supply usage and gives a baseline to compare extraneous supply usage to. Note: this initial dynamic hypothesis is merely a tool to support research efforts. It highlights some of the key research areas, such as patient satisfaction and how supply usage is tracked.

A simulation model can be created with a reference mode and a dynamic hypothesis, though the initial dynamic hypothesis is not always right. Research can quantify qualitative relationships expressed in the dynamic hypothesis and it is often unfeasible to do experiments,

so research will be heavily relied upon to quantify causal relationships. Sometimes these qualitative relationships will instead be established using known rules of system dynamics and tested around normalized conditions for ease of creation. Testing will be completed during and after the creation of the simulation model. The results of the model will be compared with the reference modes. Parameters and relationships will be adjusted to increase the robustness of the model. During this entire process, iterations of the model will be reviewed with the sponsor team for feedback.

After satisfactory testing, leverage points on the model can be determined through sensitivity analysis. This analysis can also assist in determining policies for solving the problem. The next step is to test how the policies influence the model and to derive conclusions from the results. It is important to iterate each step in order to optimize the validity of the model. As progress is made, changes to the policies, simulation model, and the dynamic hypothesis are all possible and can be enhanced with feedback from ECHN.

2.2 Identification of Limits and Model Parameters

A number of assumptions about the model must be designed to quantify possible scenarios. These assumptions must take many factors into account, such as the acuity per patient per nurse ratio, base supply usage rates, and the effects of the planned countermeasures in the system.

The first assumption determines the extent to which the base patient/acuity/nurse factors can fluctuate on a monthly and a yearly basis. Such random fluctuations affect the base

supply usage for the hospital and make modeling difficult, so the first step is to normalize this relationship. A constant level of acuity for a constant number of patients and nurses more readily creates the hospital's reference mode behavior for supply usage. Data provided by ECHN will be used to determine realistic coefficients for this scenario as reflected by an average number of widgets needed to treat each patient. Nurses will also stay the same, leaving the main variance in the number of patients as this has an effect on shortcut usage. For the model, the system will have a base equilibrium of 10 nurses watching 10 patients each who require 10 widgets worth of medical supplies to properly treat.

Excessive Supply usage can be estimated with two methodologies. The first method is to compare the actual supplies used with the budgeted amount for the nursing line. The second method is to interview nurses on the line to determine their own perception of the situation. Based on these calculations, budgets ran about 10% over, as seen in Table 3.

	Actual	Budgeted	% Difference	Monthly % Difference	Variance	Monthly Variance
07	47,800	43,900	108.88	9.07365	3900	325
08	46,700	43,800	106.62	8.88508	2900	242

Table 3 : Budgeted vs. actual supplies for Nurse line 3 North (in dollars)

In an ideal world, budgeted and actual supplies would be exactly the same. One factor which accounts for these differences is the factor of patient days, or roughly the budgeted number of patients for each unit. If nursing lines end up with more patients than they are budgeted for, they will struggle to keep up, a factor which can lead to shortcut usage. However, this variable will require additional testing as it appears there is not currently any form of feedback towards the rest of the model. Additionally, not all medical items are charged to the patient when used, but for simplification each widget in the model will have a value. This

allows us to average the value of widgets with extremely high value versus widgets which cost nothing to the consumer, but still cost the hospital. It also highlights the fact that the hospitals IS system cannot tell the difference between misused items and uncharged billable items.

The nursing staff's resistance to change will be a difficult variable to determine and will require deep testing. The resistance could possibly be represented by a delay to changes in Psychological safety and Price awareness. These two factors reflect both stressful pressures and ongoing educational efforts respectively. With Psychological safety, there is likely a point where management and economic pressure would stop having an effect, and should be shaped as such in the final model. A way to estimate this resistance will be nursing interviews to determine their reaction and effectiveness of efforts made by ECHN thus far.

2.2.1 Administrative Data

ECHN administrative data provides parameters for the estimates of some of the variables and the rough qualitative data underlying the model. Unfortunately, due to the nature of the data needed for the some parts of the model, there are some gaps requiring additional details. The first significant piece of data represented the actual versus budgeted amount for the target nursing line as seen previously in Table 3. Additional hospital financial data reflected the motivation for the targeted changes but was not required in the final model. Budgeted patient days vs. unbudgeted patient days also provided useful data in creating parameter estimates for the final model.

One area lacking data was the specific breakdown of individual widget costs and common problem supplies on the lines. ECHN's current Information System (IS) tracks supplies

bought by each line and can attribute supplies paid to a line, but it cannot give a breakdown of which supplies ended up used in shortcuts and over treatments. The information provided also highlighted a third potential area of loss, namely the actual value of which were not charged to the patient, as both the hospital's budget and the nursing line budget lost money from this income. But nursing lines are rarely tracked and punished for uncharged items, so the rest of the hospital also bears the cost. In addition, it is not feasible using the current IS present in the hospital to efficiently track an entire nursing line's uncharged items, though pharmaceutical usage can be tracked thanks to a slightly different system.

Patient satisfaction reports, whose confidentially keeps the exact data out of the final report, proved to have only at best tangential evidence to the effectiveness of shortcut usage. Since feedback indicated the same patient satisfaction on high yield patient days as low yield patient days, this could potentially mean that lowering the occurrence of shortcut usage could affect patient satisfaction. At the same time, if shortcuts are being used constantly already without a change in patient satisfaction, then there may be little to no effect. Patient satisfaction will likely be based around the idea that the nurses' training and perception will affect their resistance to change, especially in shortcut usage, more than the individual patients. Regarding over treatment, the only possible change to patient satisfaction could be from nurses spending less time with patients.

2.2.2 Additional Interviews

In addition to the data provided by ECHN's direct liaisons, a series of interviews was set up with members of the nursing staff. The questions for these interviews can be found in

Appendix B and were designed to evoke thoughtful responses rather than elicit specific replies [30]. The primary goal of these interviews was to determine the nurses' views regarding the issue and to see if recently implemented momentum policies had any effect on the nursing population's habits. A secondary goal of the interviews was to better estimate parameters such as failure to charge, overtreatment, and shortcut usage.

The interviews provided a number of key ideas and concepts to work into the model. First, nurses would always prioritize patient care and well being over inventory and supply usage control measures. If a nurse felt that a patient was not satisfied, that issue would take priority over attempted control measures. Nurses who ranked supply control as an important still stated that if they were busy they would focus on attending to all their patients first. Second, most nurses were often unaware of the importance of supply control until recent meetings and news of layoffs from around the hospital. This reflects an underlying problem with nurse training and the lack of education pertaining to financial management and repercussions. Thanks to recent efforts, especially reinforcement at normal weekly staff meetings, many nurses had become more consciousness of their supply usage. Finally, the meetings revealed that nurses often put a premium on understanding how expensive a supply was. This fact helped them to remember to use the price stickers which they frequently forgot to use. This also had the added benefit of helping nurses feel closer to patients, as better price awareness helped them inform patients of how to take care of themselves when discharged.

[30] (Doyle, 2006)

2.3 Creating the Simulation Model

2.3.1 Client Presentations and Final CLD

Throughout the modeling process the structure of the core model was presented during the sponsor meetings at ECHN for additional feedback and to keep the model within ECHN's parameters. As a result of these meetings, additional modifications, and in some cases simplifications, were made to the model. The client presentations highlighted the importance of approaching the main problem from the perspective that nurses were taking shortcuts. They also helped identify an additional problem, that of supplies not getting charged to the patient.. Drawing on these presentations and additional research such as the nursing interviews, a new CLD and problem statement were formed. The final problem statement is "To reduce the number of uncharged supplies being used by the target nursing line."

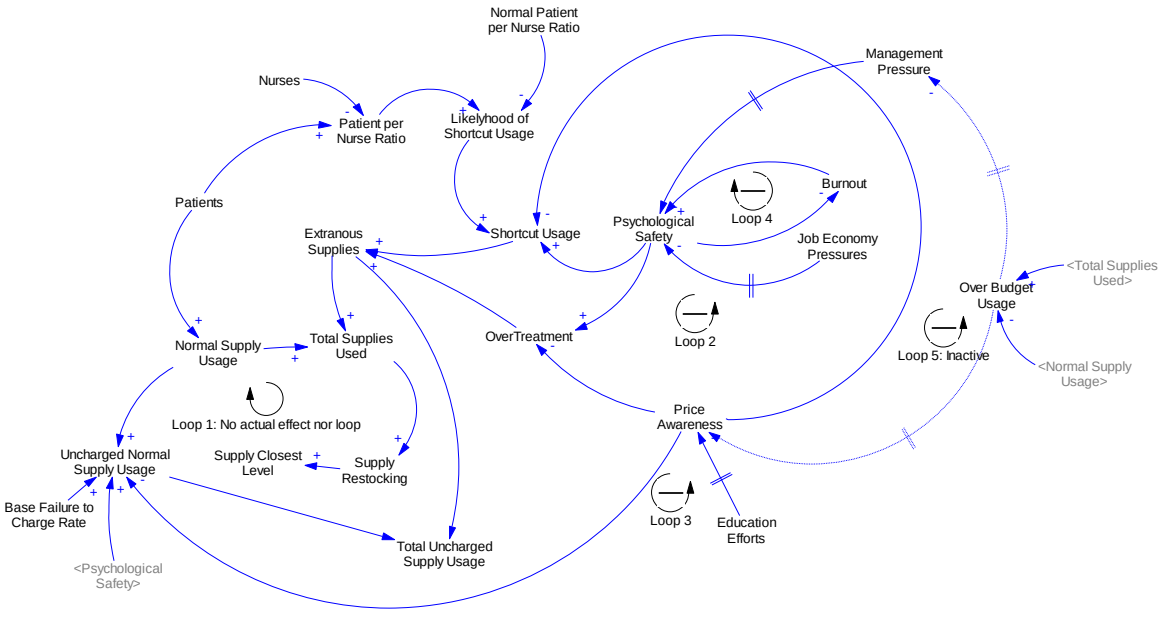

Figure 8: Final Casual Loop Diagram

The first major area in the revised CLD and dynamic hypothesis is the lack of feedback present in the model. This is due to the focus on a single nursing line rather than the greater entity which is the hospital as a whole, effectively acting as an insulation for the system. The reason for a limited scope is that it better allows us to focus on policies specifically geared towards nursing lines and allows for a manipulation of various scenarios[31]. This is representative of the lack of control and feedback currently active and available to ECHN and is a more realistic fit for their problems.[32] For example, as a non-profit hospital ECHN cannot reduce the number of patients to offset costs easily. Nor can the company afford reign in problem nurses through the expensive process of hiring and firing in the current market. A further example of an area lacking feedback, especially on a usable timescale, is the area marked Loop 1 in the diagram. Since stocking is almost instantaneous, the daily stocking of the supply closet levels has no bearing on total supplies used.

Loops 2 and 3 represent the resistance to change for the nursing staff in the form of delayed reactions to external pressures and educational efforts. The effects on psychological safety and price awareness are not instantaneous. The model will be designed such that high psychological safety makes a nurse feel safe and secure in her job and therefore more likely to fall into habitual mistakes. High price awareness, through strong educational efforts, creates reduced losses.

[31] (Warren, 2004, p.332)
[32] (Warren, 2004, p.333)

Loop 4 represents the limitations presented by psychological safety, namely during times of extreme stress for extended periods. The effect can burn a nurse out, negating the benefits gained from a low psychological safety on supply problems.

Loop 5 is a potential but currently inactive loop for ECHN. The loop represents the factor ECHN can track when they are going over budget and allows them to adjust their efforts in management pressure and educational. Historically usage of this feedback has not been a high priority issue until recently.

A considered model sector, but ultimately unused, would be a financial sector for the model. Such a sector would like ideas related to dollar amounts such as: the price of educational efforts, uncharged supplies, management pressure costing managers' time, and short term capital investment for long term gain. Currently ECHN's primary concern is not balancing the costs of the various options and solutions presented; they are instead focused on finding simple, small changes which can be designed around cheap curriculums. Though financial variables like total uncharged supplies will appear in the final model, they are not the only important factor in decision making. Another element dropped from this version of the model is the idea of patient satisfaction, an area of quantitative weakness. The concept of patient satisfaction was instead replaced by nurse's commitment to attend to all their patients in a timely manner, reflecting the call of shortcuts during times of high patient volume.

2.3.2 Policy Insights and Reflections

Before creating the final model, some key restrictions and potentially policy changes which will need to be observed. ECHN only recently implemented countermeasures to control

the disposable medical supply problem. This occurred right around the time the United States economy started showing deeper signs of distress in late 2008. Including manual triggers in the final model will help account for this fact. Based on interviews with nurses, the four key elements currently affecting disposable medical supplies are management pressure in the form of layoffs, economic pressures, a single education meeting, and smaller continuous education efforts.

The goal is to reach as close to normal supply usage as possible, and to make sure that normal supply usage is properly charged for. Feedback indicates that getting a perfect system is likely an unwinnable goal, but the model should come close. There will almost constantly be a low level of over usage even in the most ideal system, and nurses indicated strongly that shortcut usage will occur during high pressure situations no matter what.

2.3 Simulation Model

The next step in developing this model is to translate the qualitative representation of the problem, seen in the last Causal Loop Diagram in Figure 8, into a quantitative representation that uses mathematical equations to represent causal links. By doing so, the model provides a structure to analyze the movement of supplies and their uses within the system. The simulation model structure can be seen in Appendix C, and for ease of explanation, will be broken down into components smaller components in the following pages.

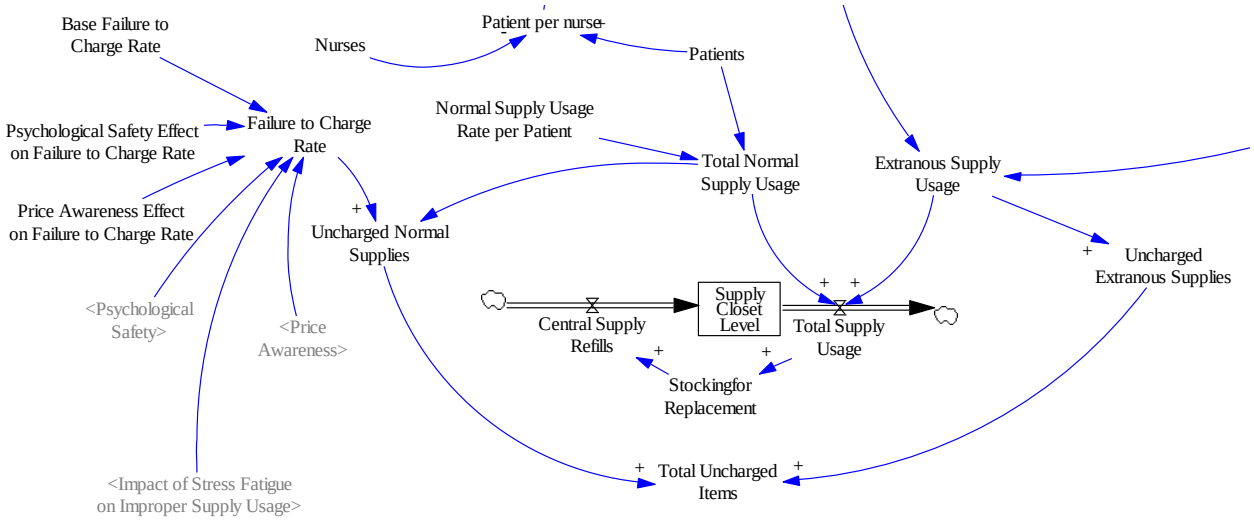

Figure 9: Failure to Charge and Supply Line Model Components

The first major occurrence in the model is the fact that supply levels, at the moment, do not dictate usage for the system. The supply closet level for each nursing line in the hospital can be filled on an hourly basis during an emergency situation, and as such the day to day fluctuations barely registrar on a monthly timescale. These elements are still present in the model to provide an opportunity to expand and test out additional scenarios in the future. The number of supplies used for total normal supply usage is dictated by patient numbers, while extraneous supply usage is calculated from total shortcut usage and overtreatment. Said extraneous supply usage should be around 10% above total normal supply usage when fit for ECHN. On the left side of Figure 9, some of the normal supplies used are lost due to the failure to charge rate, calculated to be around 0.2 based on nursing interviews. This supply line error is either weakened or compounded by the models three main leverage points: psychological safety, stress, and price awareness. Note that price awareness and psychological safety are potentially calculated differently for each variable they influence, whereas stress is considered

a universal constant. In this case, price awareness is weighed a bit more heavily, as many interviewed nurses reflected on how drastically they changed their habits when they realized the true cost of supplies.

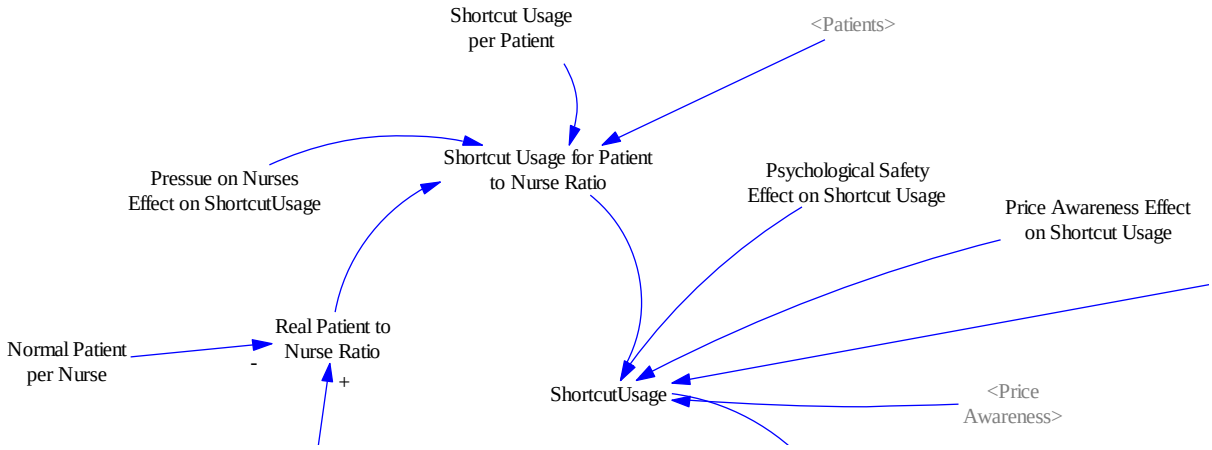

Figure 10 : ShortcutUsage Model Sector

The Shortcut Usage sector shares many traits with the failure to charge sector seen previously in Figure 9. But the major change lies in the calculation for base shortcut usage rate, represented by Shortcut Usage for Patient to Nurse Ratio. Rather than relating shortcuts to patient satisfaction, the final model instead relied upon the nurse to patient ratio. Nurses interviewed stated that even with the recent crackdowns on supply usage, if they were very busy with high volumes, they would still use shortcuts to attend to their patients despite the rules. The base rate was designed with the difference between normal and real workloads in mind, so that high ratios caused a greater usage of shortcuts. In addition, a secondary difference is psychological safety has a more minor influence, as many nurses will weigh their patients before their fear, based on interviews and previously stated research.

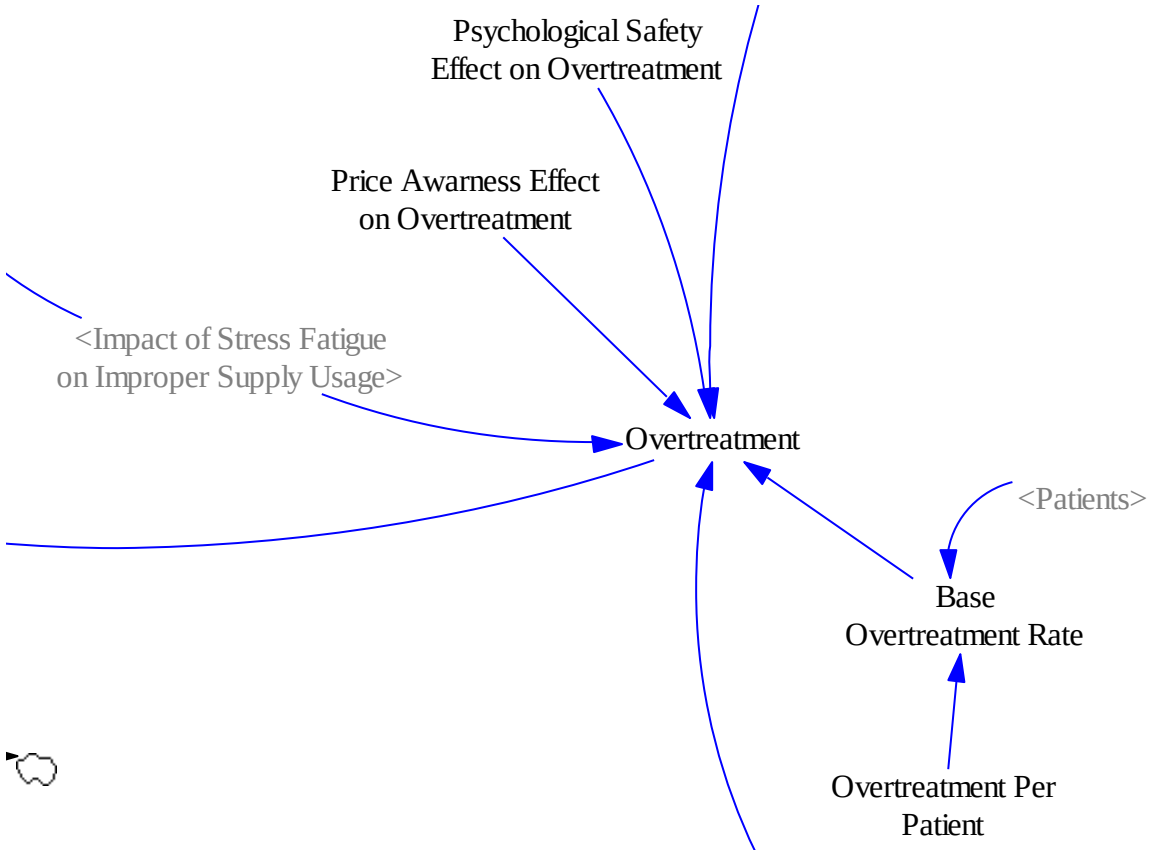

Figure 11: Overtreatment Sector

The overtreatment sector is essentially a less complicated version of the previous two sectors. Base overtreatment rate is based on patients again, with a rate of 0.5 widgets per patient to reflect the information provided by ECHN about the 3 North nursing line. At normal patient ratios, shortcut usage is also 0.5 per patient, causing the total extraneous supply usage to be 10%, roughly ECHN'S rate.

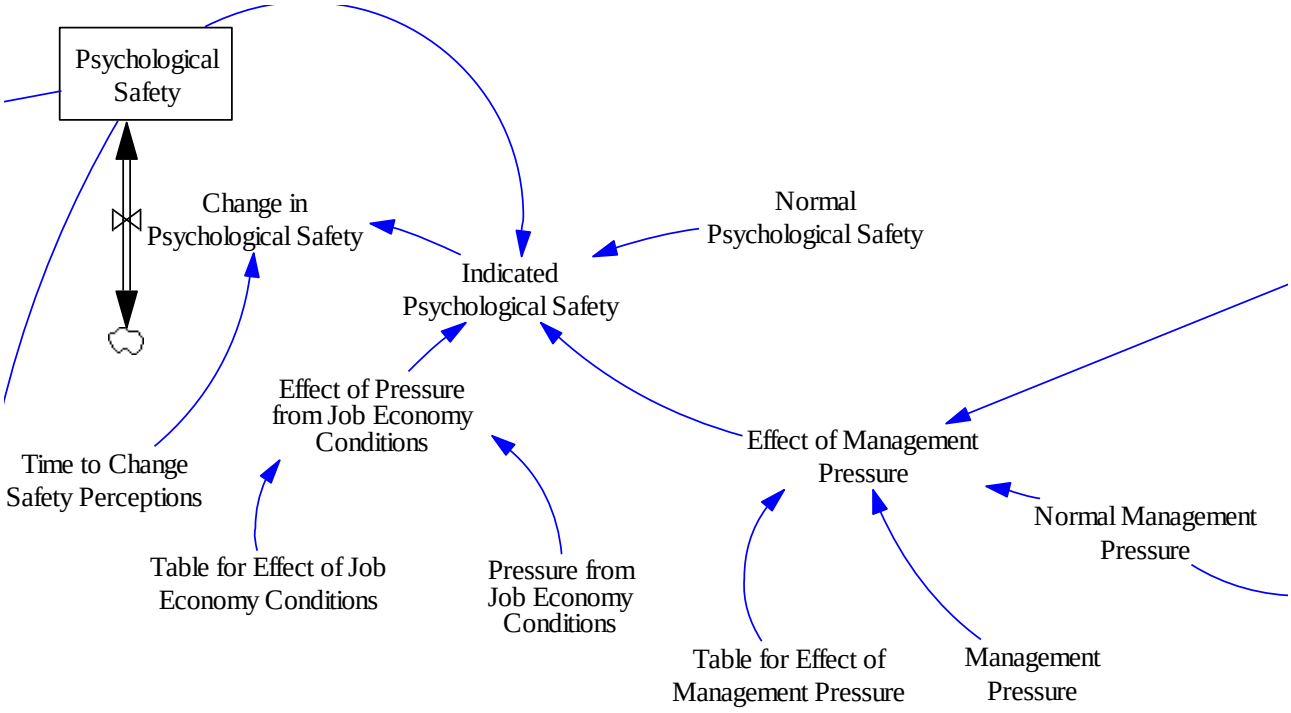

Figure 12 : Psychological Safety Model Sector

Psychological safety works from two main variables, management pressure and external economic pressures. Both are normalized around a scale of 0 to 10 for ease of calculations, and this normalization provides the added benefit of making future research easier by providing a convenient feedback scale for interviews. The two combined effects represent the pressures which cause nurses to react and worry, and their influence modifies psychological safety. Psychological safety acts as a representation of how secure a nurse feels about her position and how they react to their workloads in turn. Nurses who feel very secure in their job security, represented by a higher psychological safety number, bend the rules more easily than nurses with lower confidence. The sector includes feedback delay, representing nurse's resistance to change and delayed reactions to new pressures. But psychological safety is at best a limited tool for policy change, because strong constant pressure can lead to debilitating stress. Psychological safety and stress share a relationship similar to generic overtime and fatigue

models used in System Dynamics. Some overtime in controlled bursts can increase productivity, or in the case of the ECHN model decrease total uncharged usage. But too much overtime can also destroy productivity thanks to fatigue buildup.

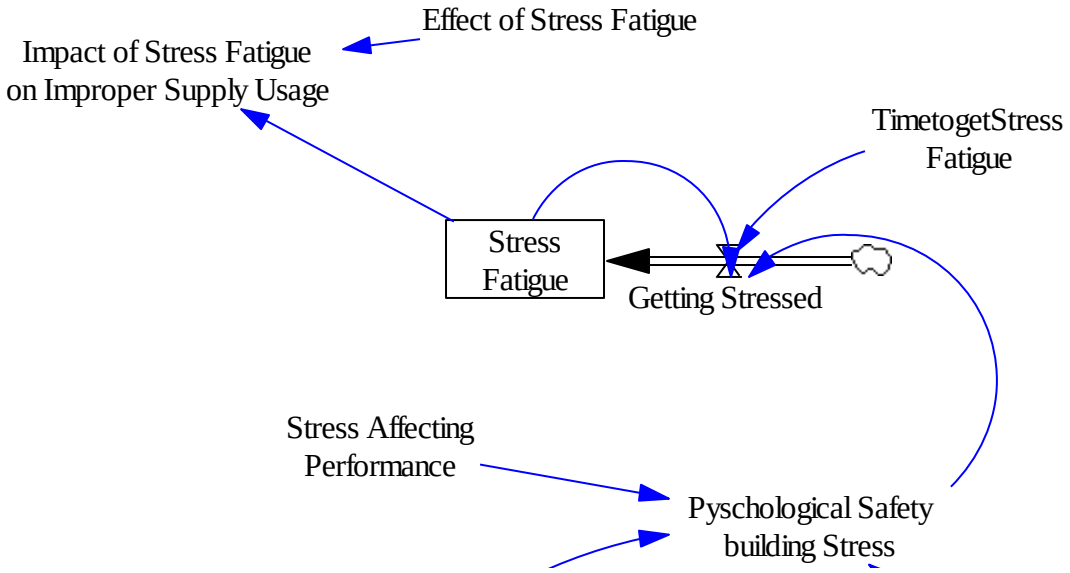

Figure 13: Stress Model Sector

In the design presented by Figure 13 psychological safety can go to zero, so it cannot be the divisor in relationship to normal psychological safety. Instead, the variable of stress affecting performance acts to turn the reversed relationship into a usable form. The variable also accounts for the fact that small variances of stress around the normal level should not create major changes to the current level of stress fatigue. Stress fatigue itself lowers even at equilibrium psychological safety, illustrating how the stock is self draining to manageable levels over time. From there, the impact of the stress fatigue itself is based around a simple effect table. Stress is a good survival mechanism, to a threshold point. A manageable level of stress actually serves to help control the strength of the supply variables, but too much stress has the potentially to turned a skilled nurses into a great waster thanks to excessive fatigue. Additional support for this idea of a stress breakdown stems from basic human behavioral patterns;

someone undergoing panic attack is mostly useless. Conversely, an individual without any stress at all likely lacks the motivation component of stress.

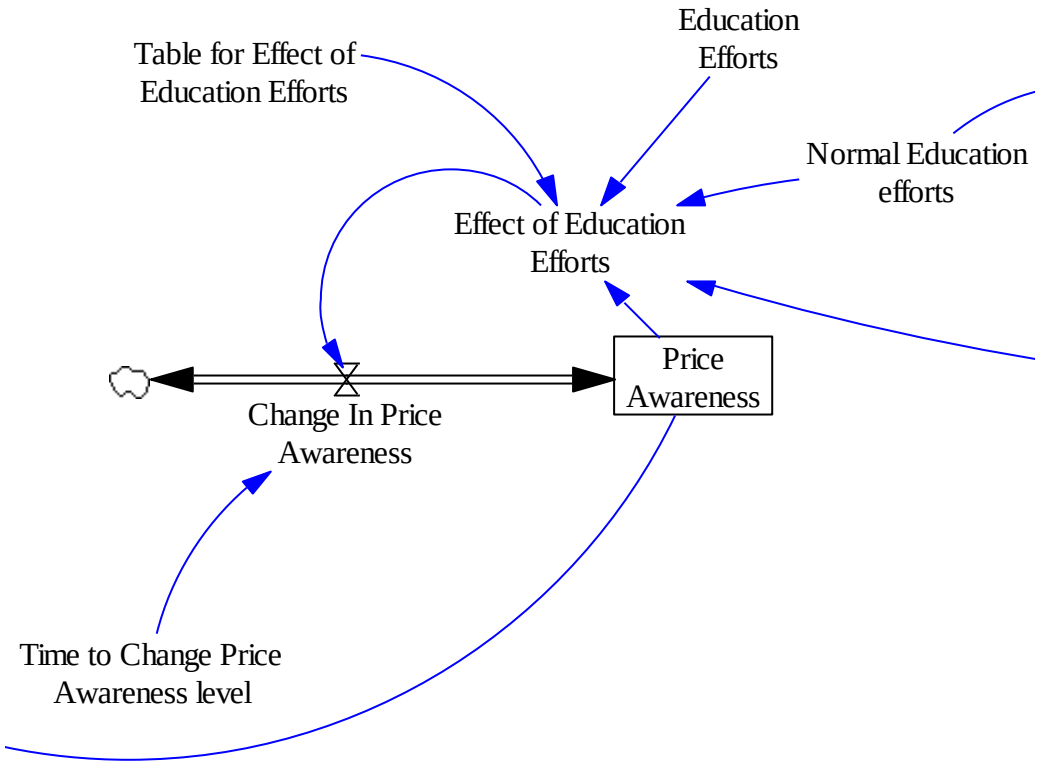

Figure 14 Education Model Sector

Structurally similar to, but simpler than, the Psychological Safety portion of the model, Price Awareness is a potentially powerful leverage point. One helpful factor is that Price Awareness reacts to stimuli faster than Psychological Safety, based on nursing interviews. This means that solutions can be implemented quickly, though the opposite for problems also holds true if solutions are reinforced. Also, unlike psychological safety, there is no competing stress to reduce educations effectiveness. ECHN has begun recently educational efforts as a countermeasure for uncharged supplies, due to the 2009 recession. This motivation was formed from external factors and pressures than rather internal feedback loops.

In fact, the model has once again been lacking any feedback, besides the delays attached to some variables. There is no way to break down the exact difference dynamics

between shortcuts, failure to charge, or overtreatment in order to determine if one problem is particularly large. Even the variable of total uncharged supplies is at best an estimate from personal accounts and limited documentation. The only known, absolute numbers of widgets come from actual supplies versus budgeted supplies. Typically responses to these two numbers are represented by single time interventions rather than dynamic policy changes. So, despite being outside the scope of the model, and likely requiring some specific managerial changes for ECHN, an optional loop was added to the core model.

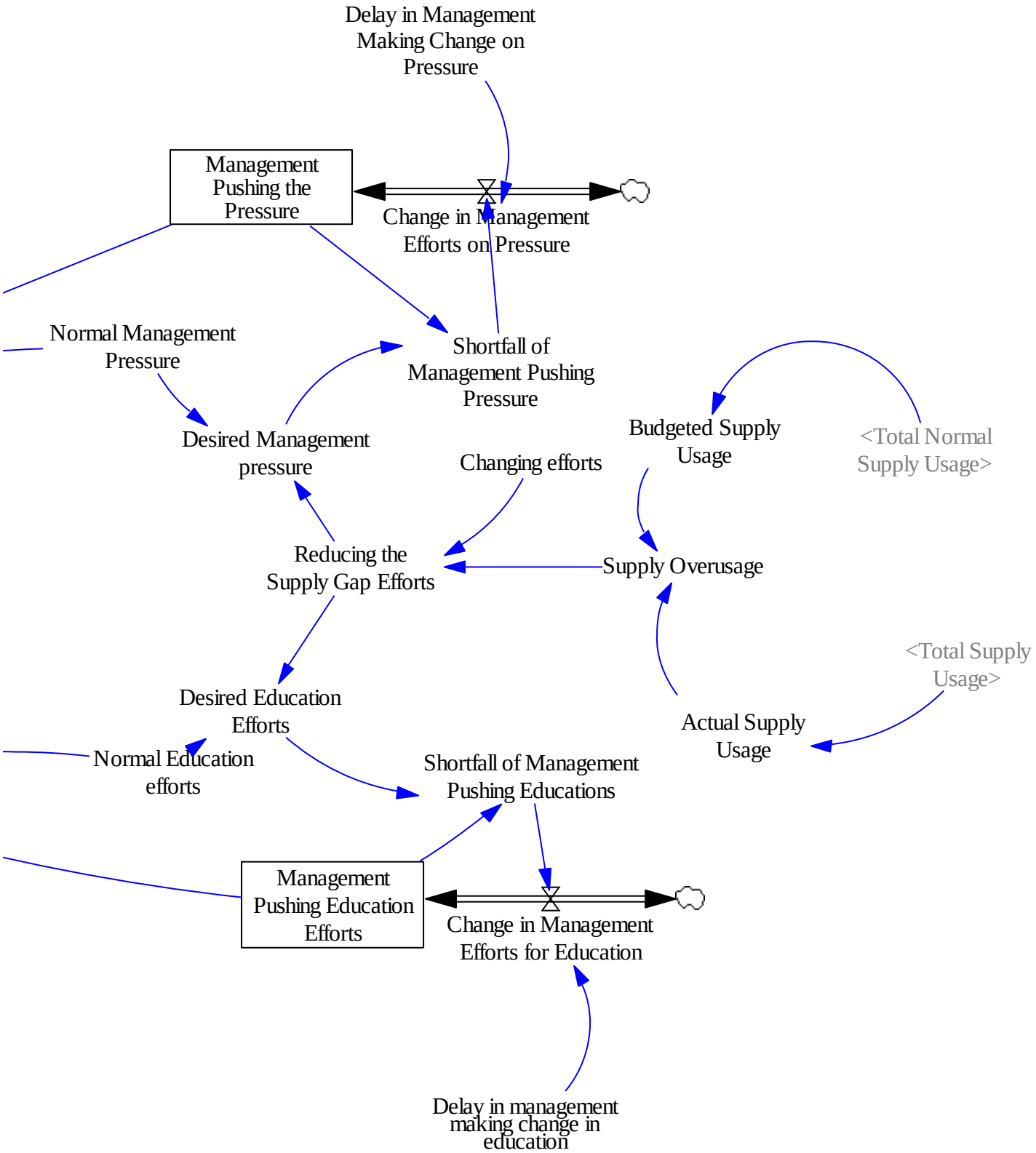

Figure 15 : Feedback for Correcting the system, Offline in Most Variations

Structurally, the feedback system focuses on the ratio between the two usages to determine the amount of effort management should put into changing variables. Delays represent the time it takes to gather data and implement programs, and the changes are based around normal levels. The variable changing efforts can be customized to represent tolerable ranges for over usage where there is no change. Changing efforts is also designed to react to the very dangerous scenario when normal usage is actually lower than total usage, implying that patients are being undertreated. Initial tests using this model provided almost immediate feedback, even with two sets of delays, which greatly reduced ECHN supply problems. However, as stated before, ECHN may not be able to implement such feedback policies in a timely manner, especially considering start up needs to coordinate a response and tracking program.

Chapter 3 Results and Discussion

3.1 Model Limitation

One of the most important simplifying assumptions of this model is that the there is no varying level of acuity among the patients, unlike the real world. Also the mechanics of patient satisfaction are merely represented through the nurses' perspective, namely their efforts to ensure everyone is adequately treatment. This is because the correlation between changing supply usage and patient satisfaction is not immediately clear, and would be a large guess at best.

On a large scale, costs are a problem which could be reflected in the model, but ultimately outside the scope of ECHN's needs. The proposed solutions focus primarily on

providing both effective techniques and simple implementations. Model limitations build for specific organizations often carry such traits and simplifications, which actually customize the model better than large more complicated equations. For example, the base calculations for price awareness and psychological safety's effect on variables are highly subjunctive. As such, the best way to calculate their shapes and scale was working with various experienced ECHN members and through testing.

3.2 Base Results and Comparisons

To test the model of the structure, an equilibrium run of the model in a steady state will first be created. This run's purpose is to help determine if behavior of the models responds to reactions the way it has been predicted too. For this model the psychological safety and price awareness variables will be attuned to ten, with the number of patients set to 100. The run will also set the base overtreatment and shortcut usage per patient rates to 0.5, and finally failure to charge to 0.2. The results for this base run should show a linear pattern for uncharged extraneous supplies and total uncharged items. Since the model does not have any decaying or growing functions at equilibrium, the system should remain stable.

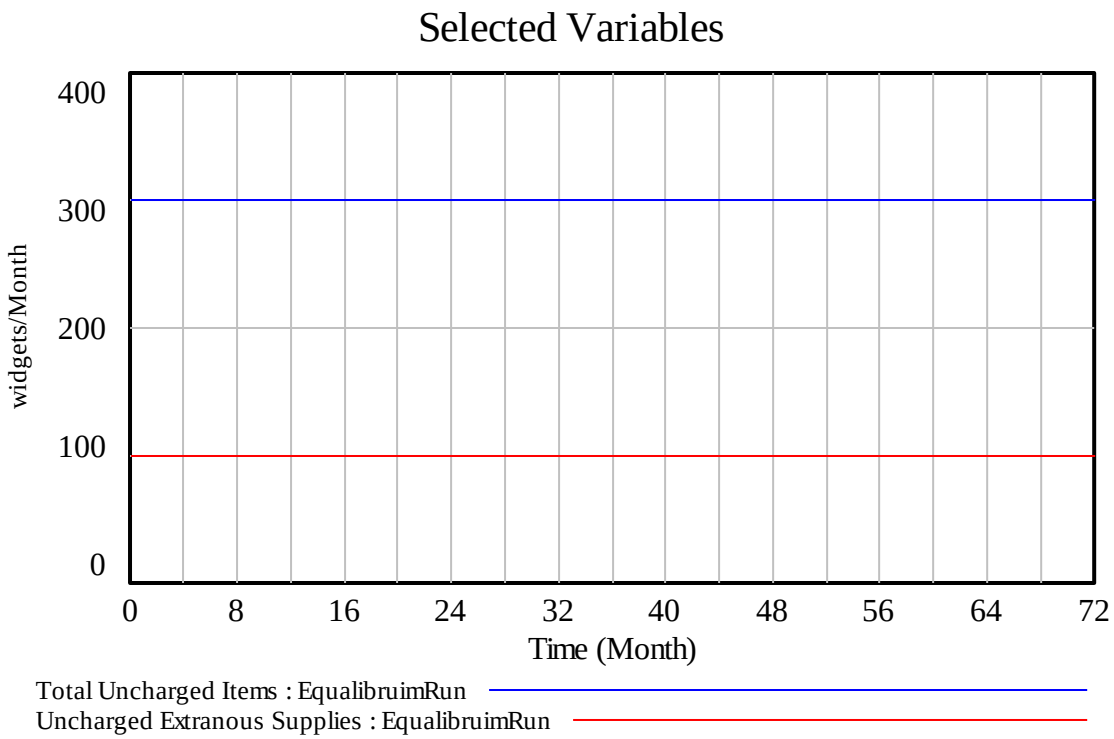

Figure 16: Equilibrium Test Run

To continue testing reference modes, we will next look at how ramping education up and down changes the total uncharged items in the model. In theory, to match our reference modes, education growth and decay should directly correspond to the model.

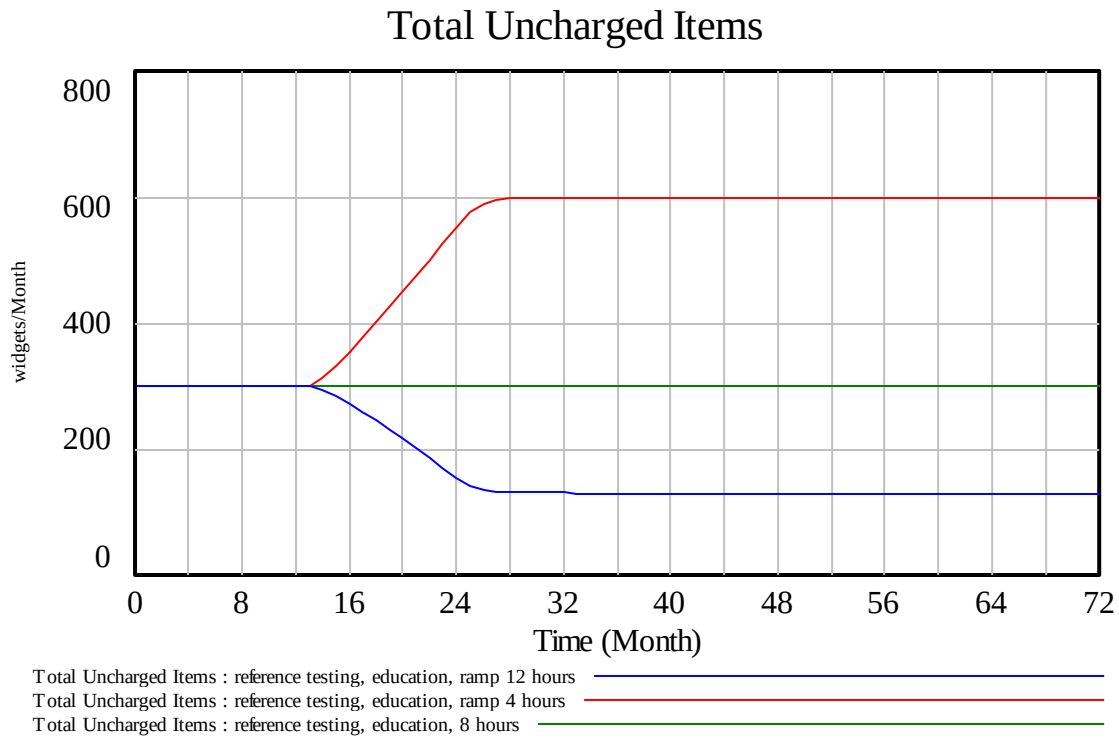

Figure 17: Education Growth and Decay Changes for Total Uncharged items

Now, looking at psychological safety, the model will start fro a base and present four different scenarios. The model will have management pressure decay and rise, followed by a similar trend with start job economy pressure already high. In theory, if the model set pressure for both job economy and management pressure to 10 each, stress would override any benefits we gain. This idea of extreme value testing will be looked at in another section.

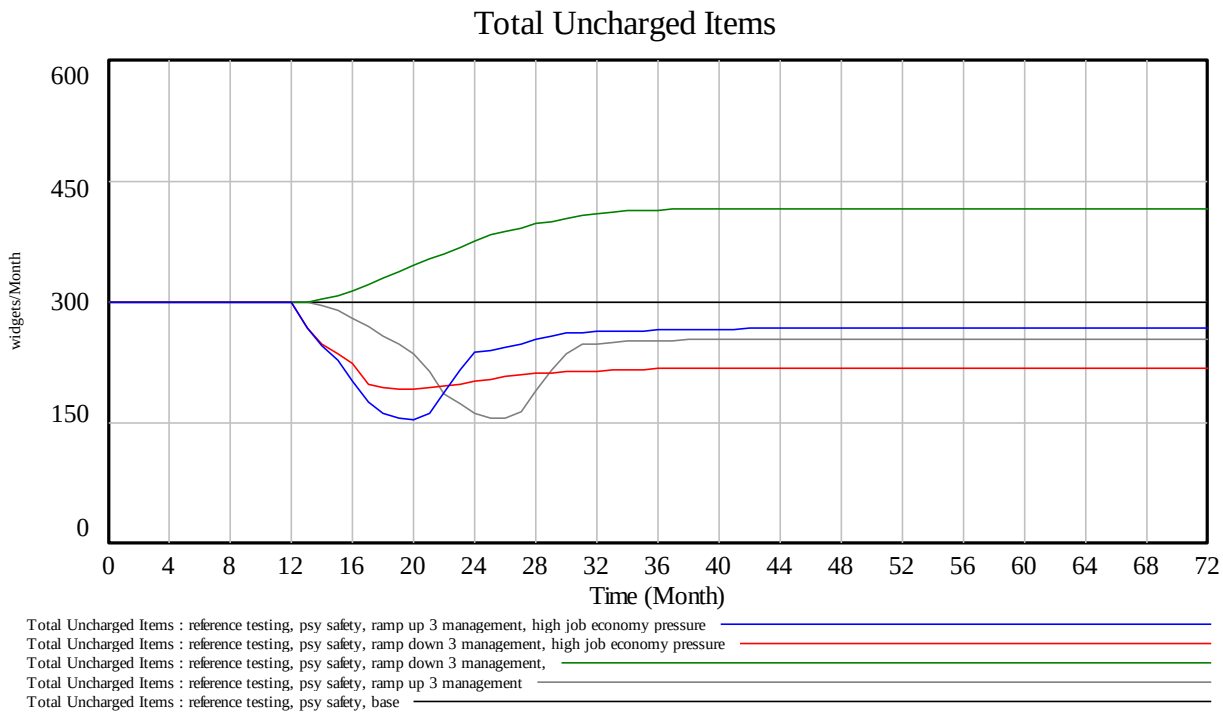

Figure 18: High Pressure but Avoiding Too Much Stress

As can be seen above in Figure 18, the behavior presented is as predicted. All the options implemented produce the desirable result of reducing total numbers of uncharged items save for the one option where management rams down pressure too much. At the same time, the behavior shows how stress weakens the impact of psychological safety when there is too much pressure on the nurses. The next variable has a similar limitation. The number of patients changes normal supply usage, the number of possible overtreatments, and puts more pressure on nurses to use shortcuts due to worse nurse to patient ratios. That means in theory, for a positive change of 50 and a negative change of 50, the positive change should have a larger impact based on the theories for shortcut usage. Also, as patient levels increase total normal usage, there are more chances for a failure to charge. Figure 19 largely supports the estimated reference modes for the model.

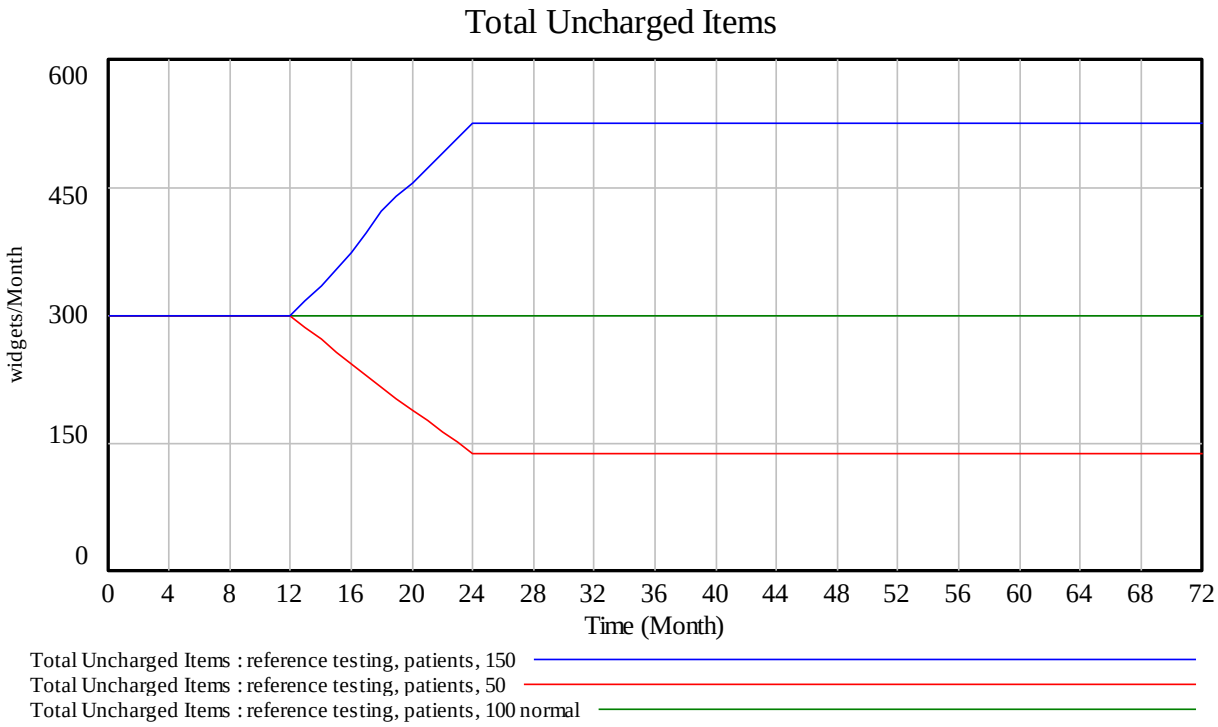

Figure 19: Patients Levels and Total Uncharged items

Next, the next model will be attuned to roughly ECHN's to match the reference modes representing ECHN's proposed current level of problems. The reference modes and employee interviews indicate that low educational efforts have been causing growth into total uncharged supplies and uncharged extraneous supply usage, and that a recent increase in job pressure has been bringing these overusage levels down back down. To be exact, the model starts with a low educational efforts to represent ECHN's limited focus on disposable medical supplies. Job economy pressure is then ramped up to represent the current economic conditions, which have had a positive effect on the amount of uncharged items.

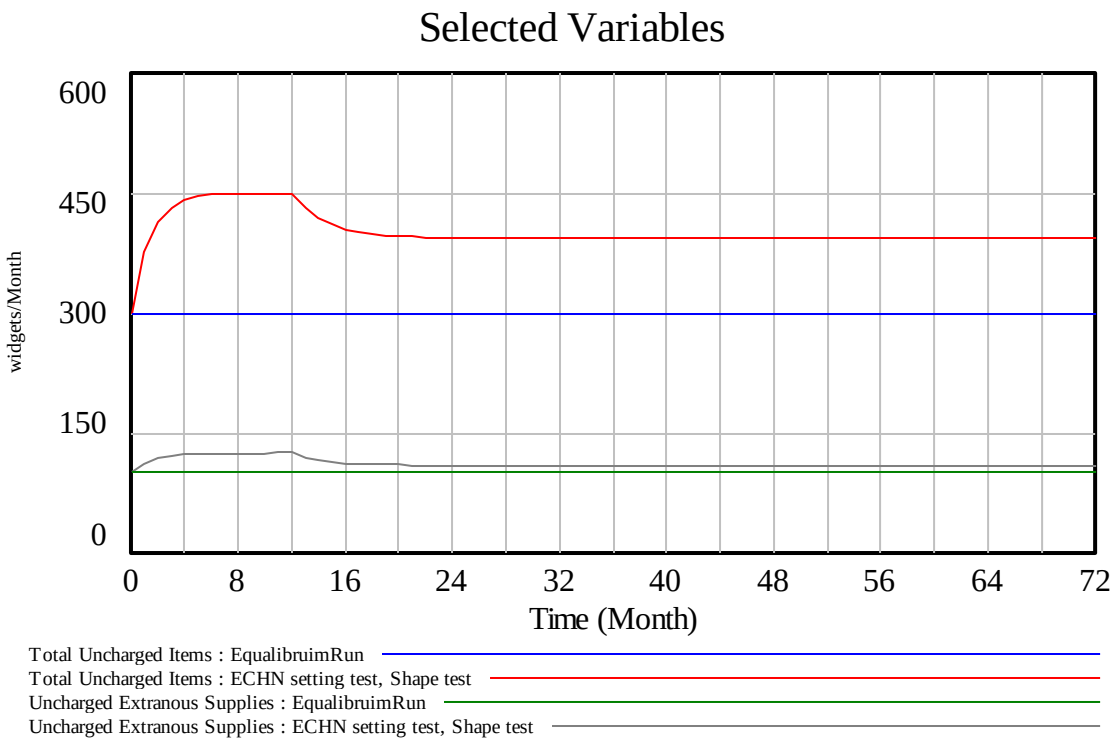

Figure 20: ECHN Reference Shape Test

The model results shown in Figure 20 largely match the proposed behavioral references modes, although it's clear that additional testing must be performed for tuning to ECHN's levels. In order to shape a range of viable scenarios, some additional testing examines how the model reacts to stimuli. Still, this does make a clear indication that the underlying causes of the reference modes can be explained.

3.3 Sensitivity Analysis

Sensitivity analysis was performed on the following variables; patients, economic pressures, base treatment rates for overtreatment and shortcuts. A sensitivity chart compares a number of likely values for each parameter and generates a dynamic set of confidence intervals the resultant behavioral mode of the model. For ease of understanding, the sensitivity tests were done on the equilibrium; the reasoning behind testing on the equilibrium is it more easily

allows the strength of individual variables to be observed. The confidence intervals result the probability of a point being calculated from a range of variable tests for a Monte Carlo distribution. These tests allow the model to represent at which points policy changes can have the largest value and impact[33].Each sensitivity chart has a line representing the shown variables base case behavior, in this case extraneous supply usage at 100 widgets. By far the largest positive variation on supplies was from patients rather than the other variable options. Patients were set randomly from a range 1 to 200 with 100 being the normal base number of patients. The variable patients dictate the usage rates for the entire model and without patients the model should fail to change. Note that the variance stretches into additional extraneous supply usage more easily as higher patient numbers create ever higher shortcut usage, while lower numbers do not possess such an impact. Note that the largest impact is a standard deviation of only 50%.

[33] (Stermen, 2000, p.885-887)

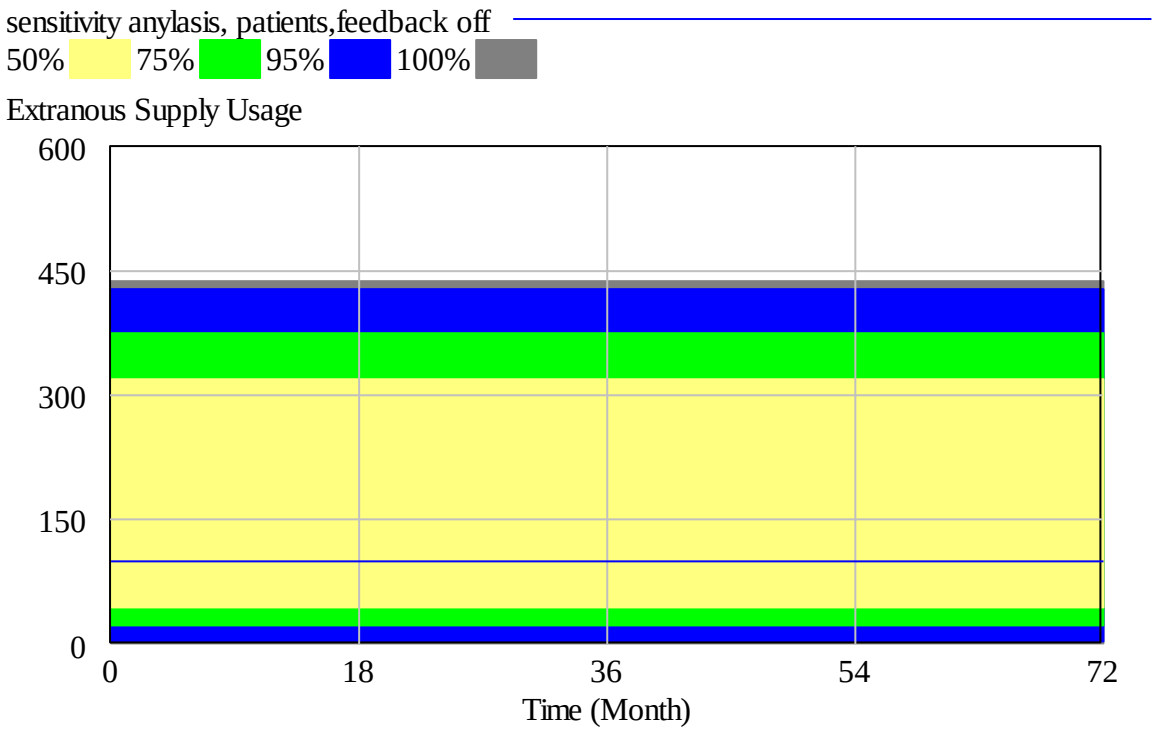

Figure 21 : Patient Sensitivity Anylasis for Extranous Supply Usage

The current model design is such that nurses will eventually reach a threshold where shortcut usage is almost maxed out, limiting growth. Another limit is presented by Figure 22, illustrating the conflicting balance between stress and psychological safety. Pressure from Job Economy conditions is a completely uncontrollable aspect of the model, dependent only on external factors. Yet this singular factor can create both positive and negative changes ranging up to 50%.

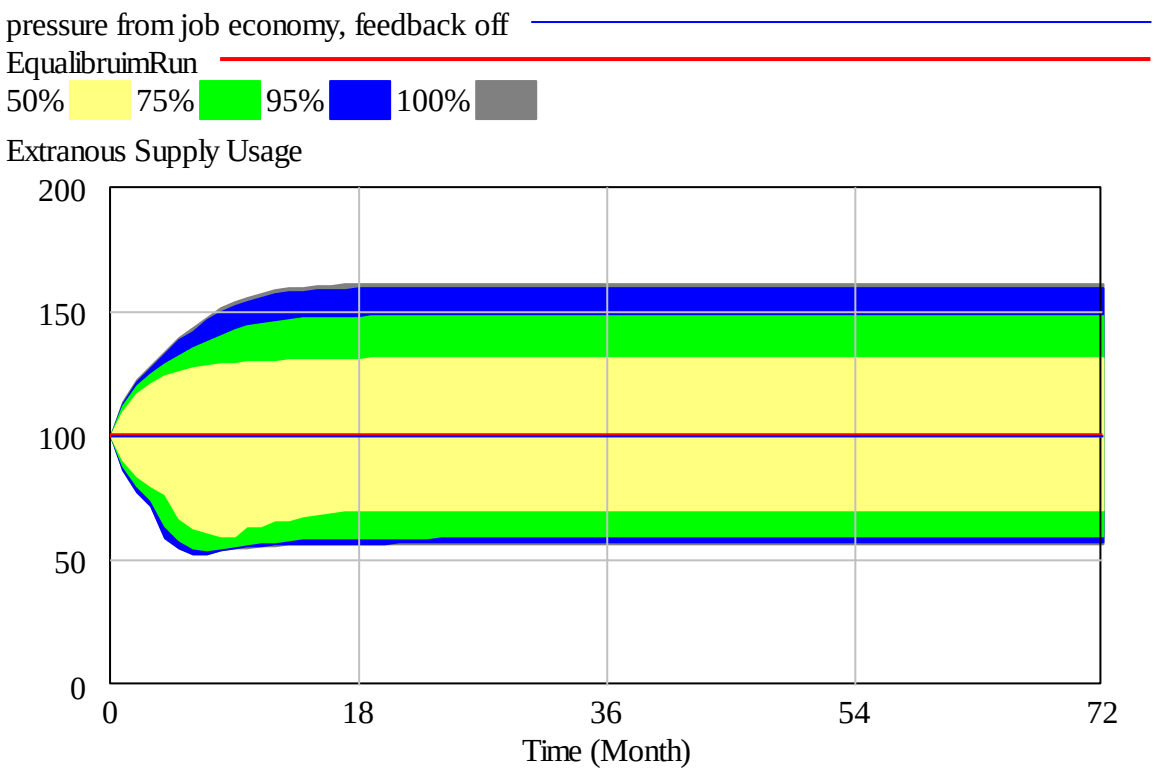

Figure 22 : Job Economy pressure Sensitivity Anylasis for Extranous Supply Usage

Figure 22 highlights the how easily important policy decisions can be influenced by the external market; job economy pressure affects the same variable as management pressure, psychological safety. If both sets of pressure are high, nurses would move closer to minimal psychological safety and maximum stress. A managerial team cracking down on nursing staff during an already stressful time period could undermine the hospital's supply lines further. The range of variables for this test was only 0 to 10, which represents the minimum and maximum of job economy pressure.

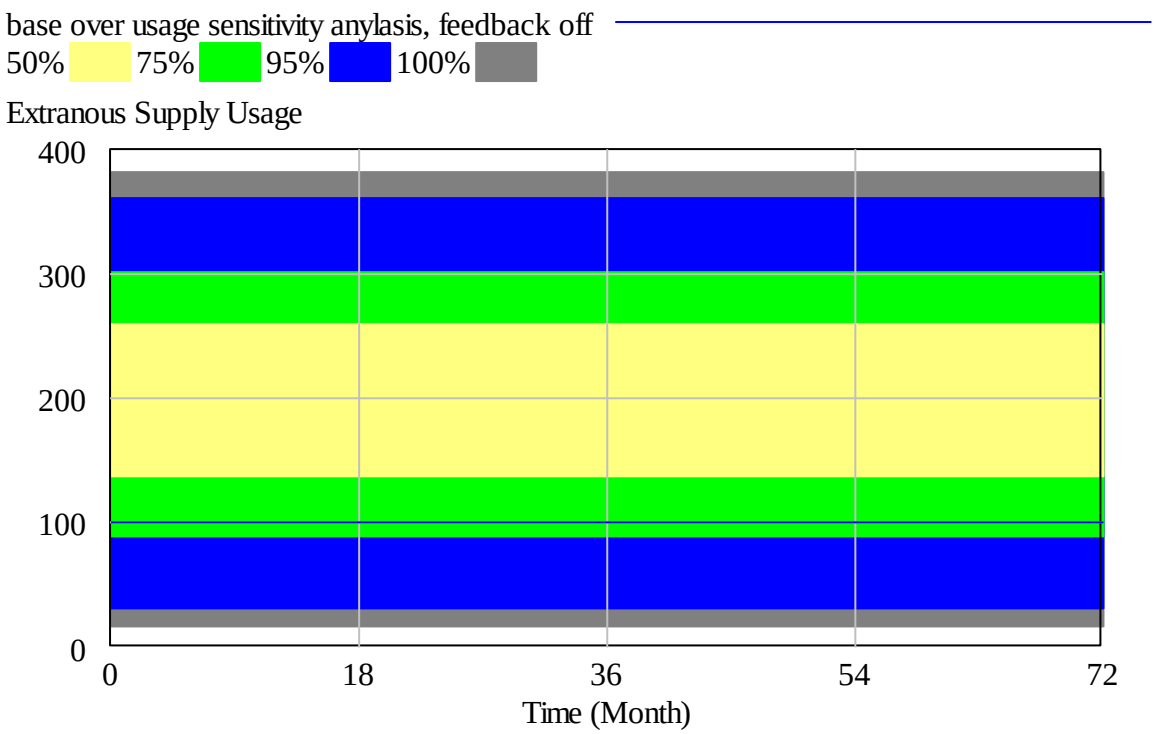

Figure 23 : Base Treament Rate Increase for OverUsage for Extranous Supply Usage

The two variables which dictate overtreatment rate and shortcut rate illustrate the fact that the model will never achieve 0 under current conditions except in some extremely rare cases. If ECHN wants to reign in extraneous supply usage and uncharged supplies then policy changes must be made, as they are already doing. If the base variables are just three times higher, the supplies see an almost 300 widget increase, and four times higher is almost 400. ECHN could benefit from a pre-emptive dampening of problem areas. That way if there was ever such a large increase, the hospitals budget would not be taken by surprise. Factors which could increase these base numbers do exist; a new patient trend of requesting overtreatment or the discovery of a handy, new shortcut could raise the rates.

3.4 Extreme Value Testing

Extreme value testing is useful in determining how robust the model is under a wide variety of conditions. It's good for determining any flaws in model logic that might have gone

unnoticed if extreme values were not tested. Extreme value testing is especially important in a model heavily formed from personnel thoughts, when mental models can end up mixed up.

3.4.1 Extreme Pressure

Minimum levels are physiological safety are possible but unrealistic. At these levels, managers would likely see little to no improvement with the amount of uncharged hospital supplies due to the high amount of stress nurses would eventually undergo. Low levels of stress should also result in very poor results since the low stress is effectively compounding the lack of worries. To test these ideas will set the pressures to both extremely high maximum values and the minimum of 0. The results of Figure 24 reflect this idea.

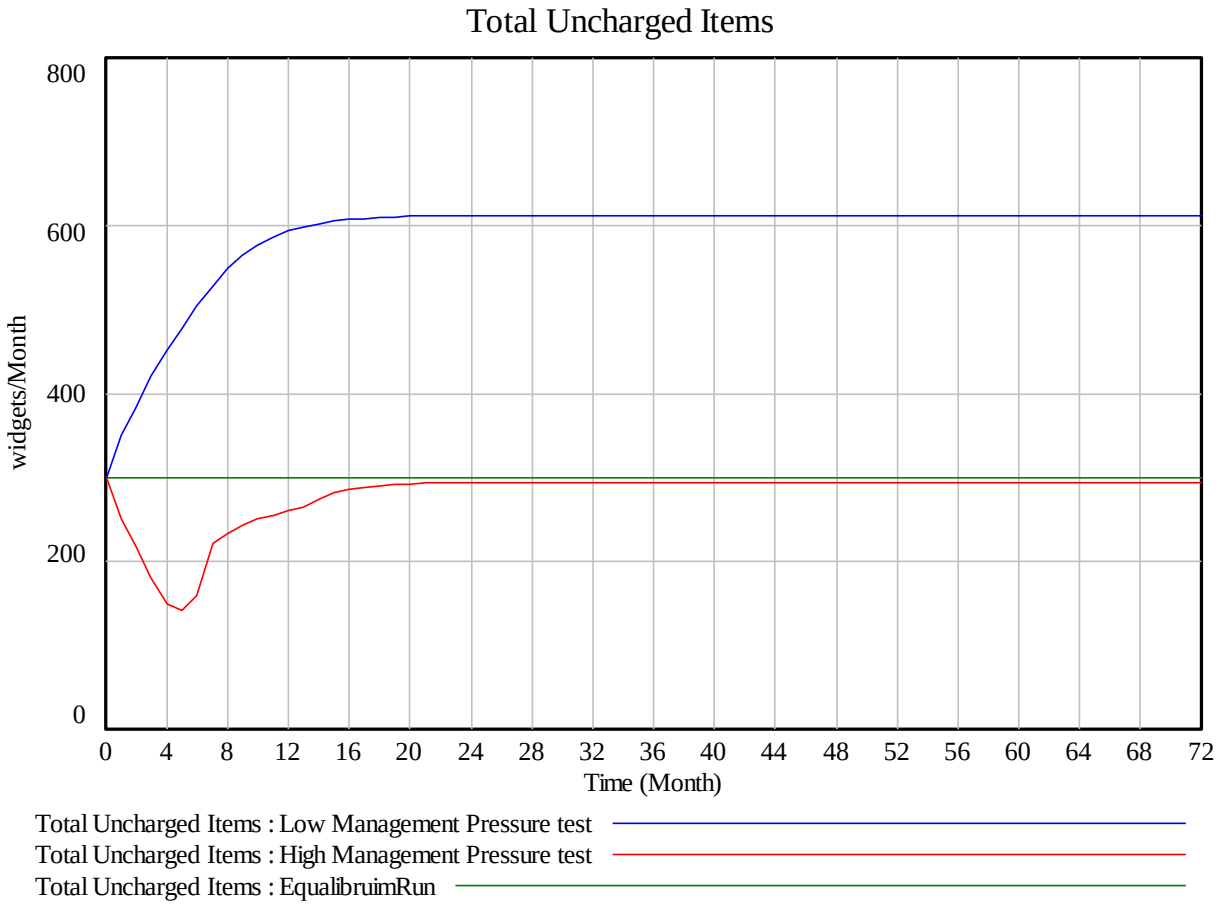

Figure 24: Extreme Value Testing for Pressures

3.4.2 No Patients

Without any patients the hospital line should just shut down, since patients dictate the how many supplies are used during every step of the process. If the model is still moving supplies, something is wrong with the line. Figure 25 fits this predicted behavior by stepping the line down to 0.

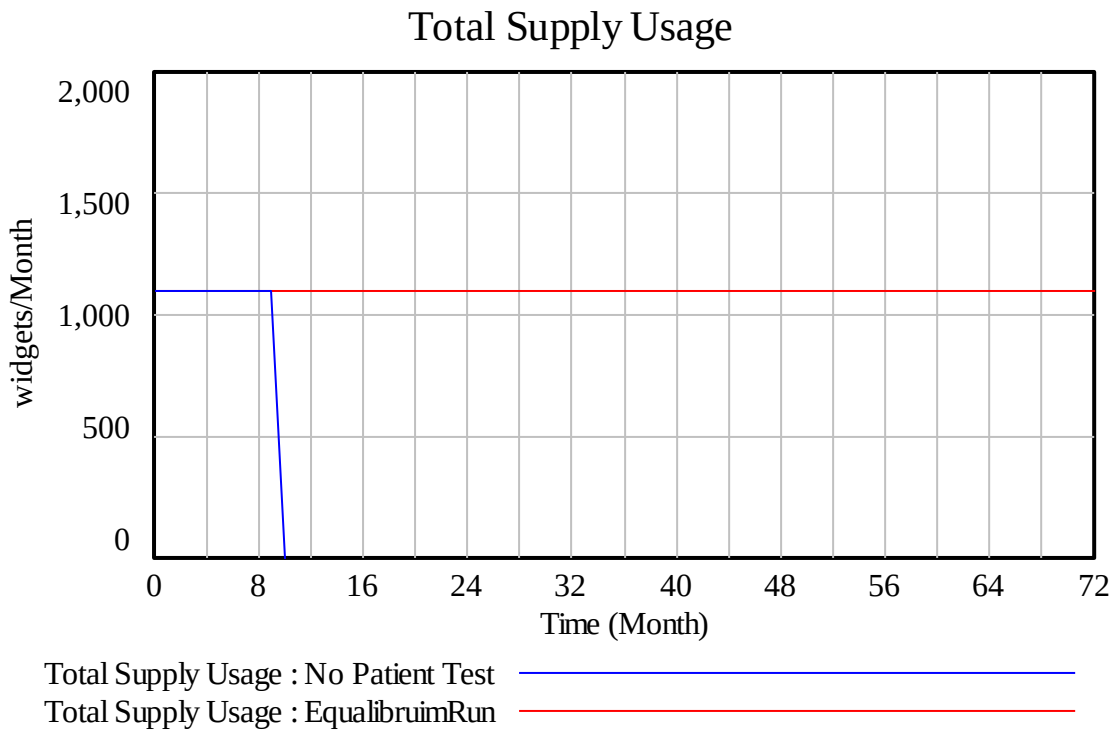

Figure 25: No Patients, No Supplies

3.4.3 No Supplies on Hand

Thanks to quick restocking, no supplies in the closet should not produce any discernable changes in the model results, nor should any errors be produced. Figure 26 supports this idea.

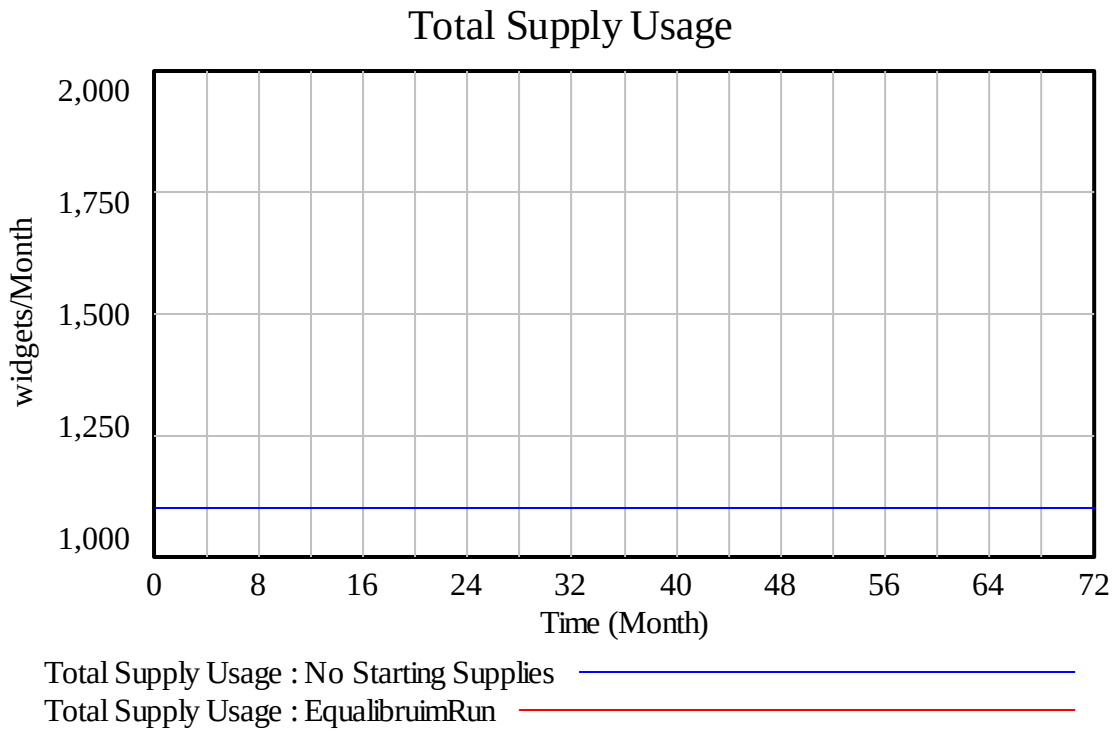

Figure 26: No Starting Supply Run

3.5 Scenario Analysis

After the sensitivity analysis and extreme value testing, the development of possible scenarios can begin. Three scenarios were tested: the “worst” case, “best” case, and “middle ground” case. The middle ground represents the parameters, designed from staff interviews, which currently make the most sense for ECHN. The middle ground it meant to be the closest to ECHN’s current situation, while the other two scenarios represent the worst and best possible case ECHN may currently be in or working towards in case the middle scenario is incorrect. Each of these scenarios will be created without any policy corrections in place so that the base shape can be determined. The values for all three scenarios are summarized in Table 4. To make policy impact more clearly seen the models will all have base overtreatment rates and shortcut usage rates of 0.5 and 0.2 for failure to charge rate, with efforts focused on variable changes.

	Best Case	Middle Case	Worst Case
Education Efforts	11 hours/week	4.5 hours/week	2.5 hours/week
Management Pressure	6 units	5 units	8 unit
Job Economy Pressure	7 units	7 units	8 units
Time to Change Safety Perceptions	6 months	3 months	1.5 months
Time to Change Price Awareness	4 months	2 months	1 month

Table 4: Scenario Analysis Equations

The variables presented in table four are all easily changeable. Time to change safety perceptions and time to change price awareness are both variables representing informational and acceptance delays. The current economic conditions can change at any moment while price awareness and management pressure can also change at any moment. The scenarios were designed to help figure out ECHN's current position and evaluate their ability to make effective changes. For that reason, during the initial evaluation process, the additional feedback loop will be activated and the base starting stock will be the same in each case.

3.6 Other Scenario Analysis

In addition to the main model, modifications were made to look at some other scenarios. Please see Appendix E for the model.

3.6.1 New Inventory System Scenario

Though ECHN is not interested in control system options due to capital costs, this model included such an idea. The idea is that if all items used could be tracked in a non-intrusive manner, then ECHN could see which specific nurses were having difficulties with hospital polices. These nurses could be worked with specifically, and as an added bonus the mere thought of knowing the hospital management knew which supplies you used would hopefully cause nurses to be more careful. The changes in the model are simple. Effectively a strong monitoring system would work similar to a closethegap function. The system could track offending supply levels and effectively react to reduce them to zero. Such a system has the potential to work since the proposed monitoring system tags both the nurse and retrieved supply automatically. However, the system is not infallible, and can be worked around. An added benefit to such a system would be a precise breakdown of what supplies nurses are using; to further highlight problem areas.

3.6.2 Shortcut Usage

An additional proposed solution was taking a look at supplies used by nurses during shortcuts and replacing those supplies with cheaper reusable variants or a disposable version of the product which could be charged for. The hope is that by doing so, the hospital can allow nurses to use their shortcuts and also partially negate excessive supply usage. The difficulty in this process is that it would require a long study to identity the most common shortcuts and not all of those shortcuts could necessarily be replaced or made into a billable item. For the model, 30% of the supplies used in shortcuts are considered replaceable, a rough estimate based on talking with ECHN officials. The additional reductions, while not large, are promising and help

negate the fact that shortcuts will almost always be used in worst case patient to nurse ratio scenarios.

3.6.3 Additional Nurses

Due to regulatory rules, the hospital is limited to a certain number of nurses per nursing line before they must add additional layers of nursing management. Most lines are already fully staffed. This problem is in addition to the general nursing shortage issues plaguing the United Sates. Still this scenario was briefly looked at and it reacted as expected. A lower nurse to patient ratio meant that there were less supplies being used on shortcuts with all other variables at their normal values.

Chapter 4: Conclusions and Recommendations

All test models will be available in .zip form with this document for further examination.

4.1 Worst Case

In a worst case scenario, nurses actually react too quickly too changes. With additional testing, it was revealed that the worst case scenario, at slower reaction speeds, actually corrected itself much better. In addition, the effect of price awareness and psychological safeties are non-existent. Psychological safety, in this worst case scenario, is cancelled due to high stress from too much pressure. The nurses act in a wasteful manner which is severely detrimental to the hospitals needs. This is not an entirely unrealistic scenario; poor economic conditions, harsh management, no educational efforts, and an "everyone is doing mentality" could harden nurses against changes to their basic routine and enhance pressures problems. This hardening however, could actual help the nurses react better because they would not be bothered by smaller fluctuations if their delays were high. Though this model stabilizes at an undesirable level, it takes longer to get there giving ECHN more time to potential catch the problem. In this scenario, job economy pressure proves to be the models undoing and difficult to compensate for.

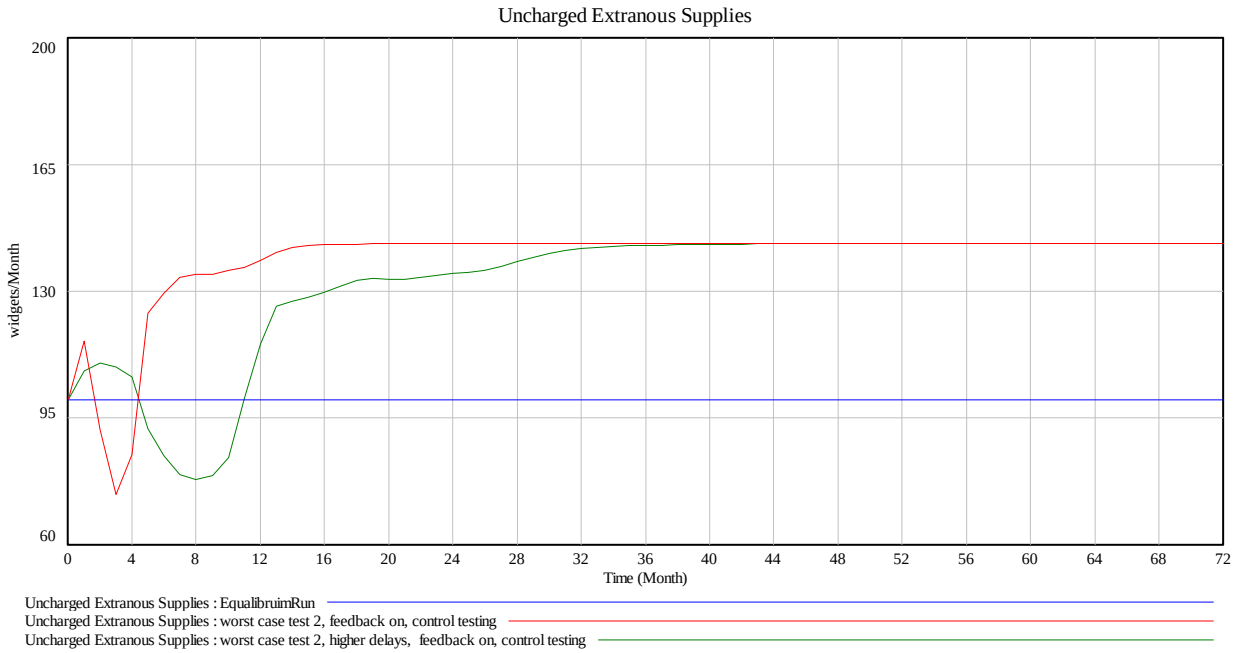

Figure 27 : Extraneous Supply Usage for Worst Scenario

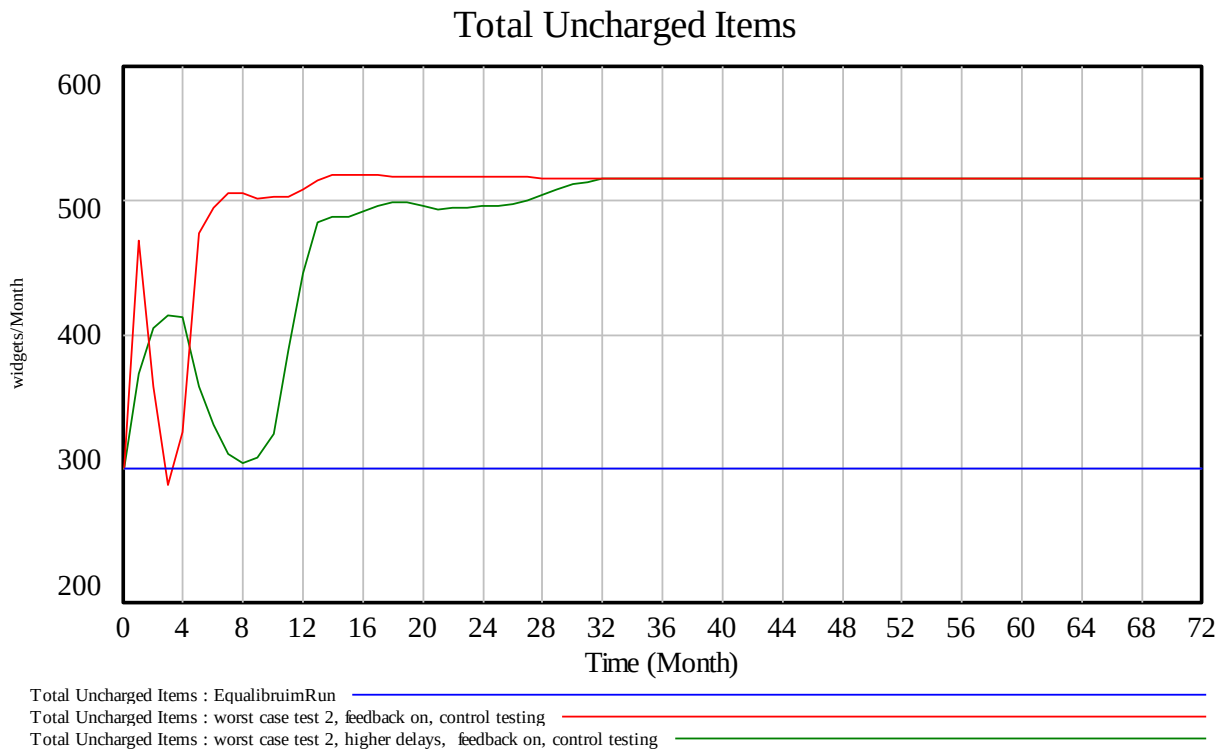

Figure 28 : Uncharged Supplies for Worst Scenario

4.2 Best Case

The best case scenario benefitted heavily from low supply usage coefficients thanks to peak psychological safety and strong education efforts. This is really the optimal scenario for ECHN as external pressures help shape policy and management pressure is not too high. However, further testing with the best case scenario illustrated that such low numbers did not react much to changes in model delays. This best case scenario may be a too good, an almost unrealistic portrayal of the nursing world, highlighted by its lack of reaction to changing delays. There is also the issue that hovering at such a high pressure threshold is very dangerous.

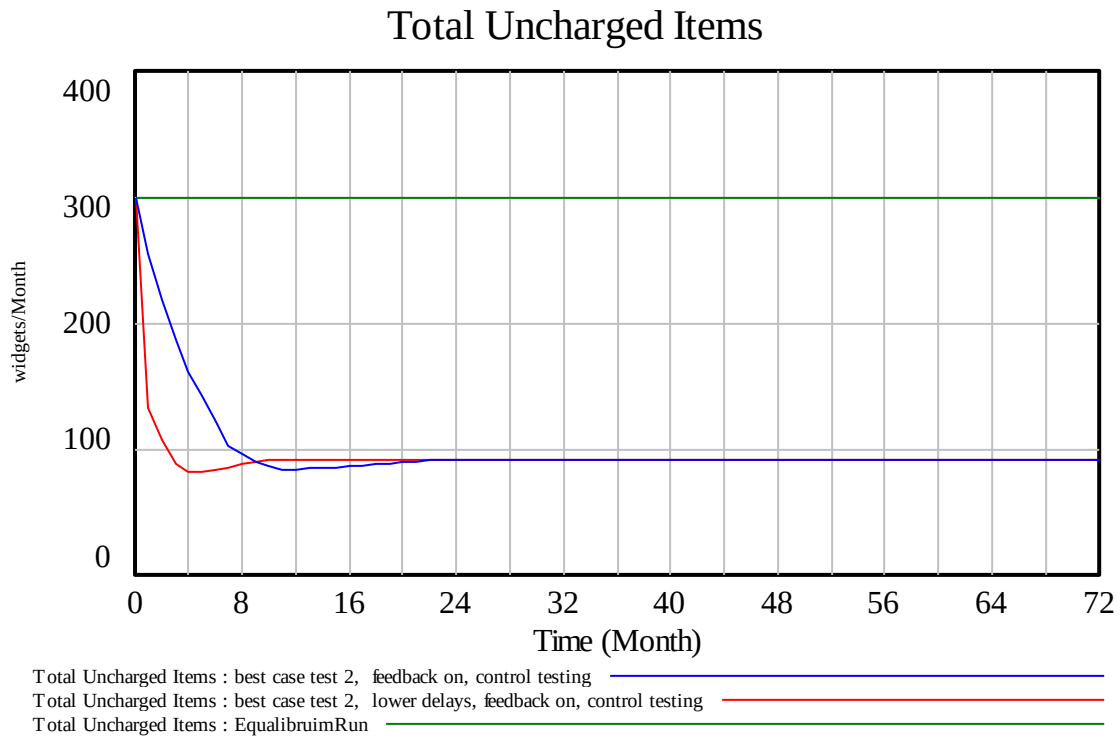

Figure 29: Best Case Time Delay testing

In this scenario, the red line has nearly 6 times the delay of the blue line, and yet the difference between the two is much smaller than expected. In fact, there is a possibility of overshoot in this policy if there is a targeted threshold in case ECHN does not want to stray too close to negatives.

4.3 Middle Ground

In the middle ground scenario the results close in on ECHN's current efforts. As such, pulses and changing efforts will primarily be tested around similar coefficients. The middle ground ran up a very realistic current scenario for ECHN's issues when feedback was on. The feedback currently built into the model is actually strong enough to bring the middle case scenario actually does bring down total uncharged items, primarily through rising education rather than management pressure.

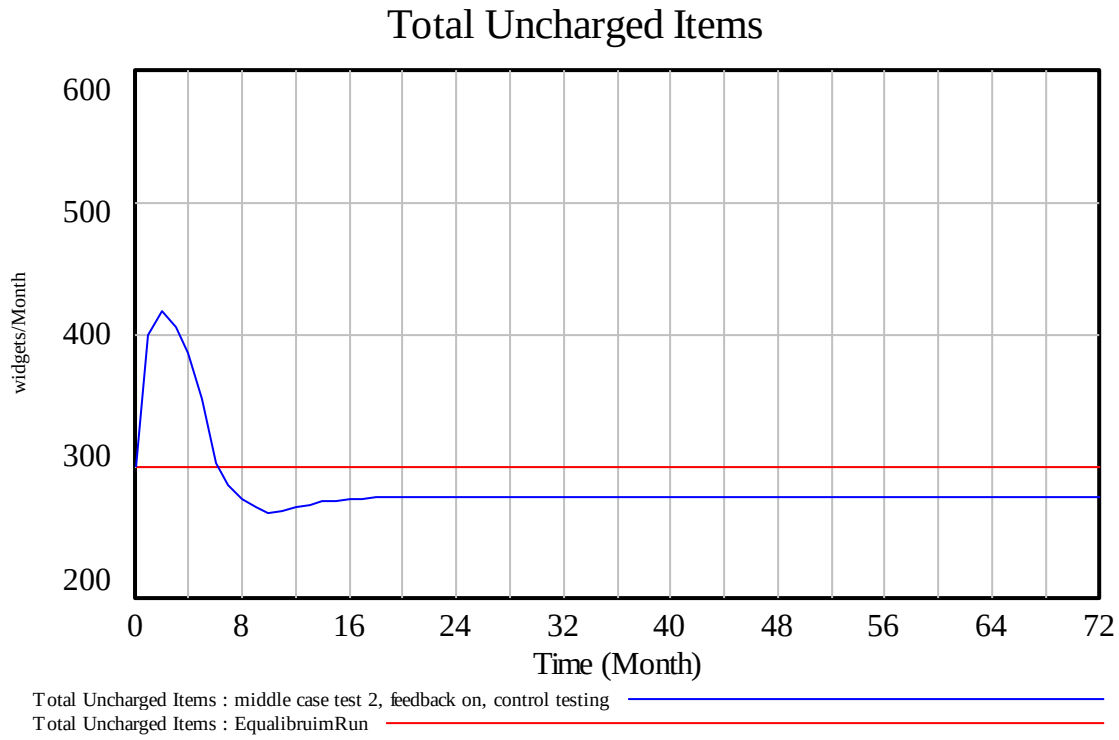

Figure 30: Middle Ground Where ECHN can Head

4.3.1 Middle Ground Education Tests

The additional model testing revealed two main concepts to consider for policy design: education needs to be continuously applied for the strongest results, versus singular pulses as

seen in Figure 31, and that the effects of relaying on management pressure in rough economic times can be very dangerous, an idea further reinforced by Figure 22 and previous scenarios at the threshold.. Testing in this model area also highlighted how much additional feedback could help ECHN, as much of the undercharging and over usage was solved by an active feedback loop.

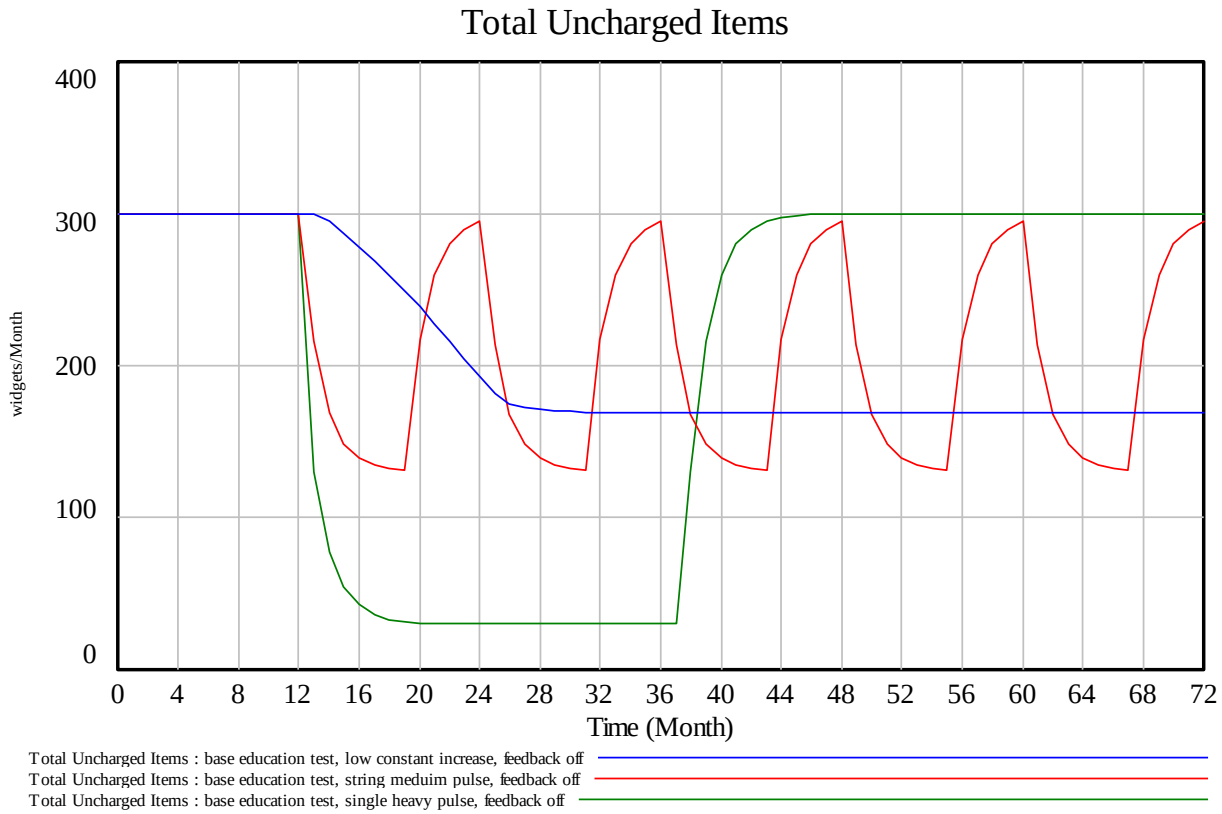

Figure 31: Power of Education

4.4 Other Scenarios

4.4.1 New IS Controls

Two additional scenarios were tested for the model. In these scenarios the model was modified to include options outside the scope of ECHN's policy options (See Appendix E). These

scenarios included capital improvements to supply controls and the embracing of shortcuts used by some nurses.

Improvements to supply closet controls suggests that if the hospital could track individual nurse usage rather than supply line usage, then nurses would be more likely to follow hospital policy and use the bare minimum of supplies. The problem is implementing such a system without it becoming too cumbersome. Many of the manual techniques to implement such a system would inversely impact nurses' ability to work. The affect of this scenario is a modification of reverse psychological safety, the idea being that if management knows you specifically are overusing supplies then they can find and respond to you more easily. It shares the inherent problem with psychological safety in the fact that in a high pressure situation, nurses will still work to help their patients first. An additional benefit of such improvements would be better overall data tracking and feedback, perhaps enough to offset costs.

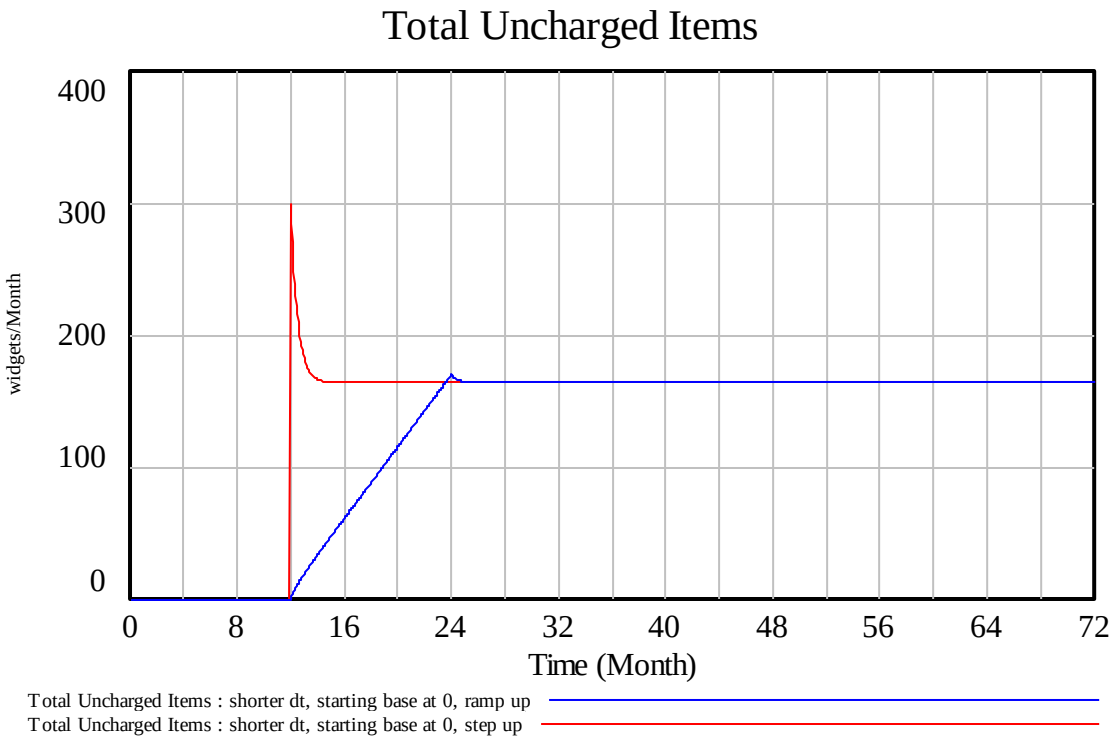

Figure 32: Total Uncharged Items and Normal Supply Usage with Supply Line Control

For the model the scenario was test starting for a base of 0 and then increasing the bases to see how the IS controls would react. The hope was that the IS controls could quickly bring down total uncharged items to lower levels and help restrain growth and overshoot. Based on the results, this is a promising but prohibitively expensive methodology.

4.4.2 Embracing Shortcuts

Even in an ideal patient to nurse ratio, many nurses still use shortcuts. As such, the next idea would be to use those shortcuts to the hospitals advantage and use cheaper supplies/reusable purposefully for these shortcuts. The advantages of this method include the ability for nurses to maintain their work rate and by extension patient satisfaction in high pressure scenarios at a limited supply cost. The models below reflect three key variables

influenced by the new model. What the model structure does is it shifts a small portion of the shortcut usage widgets into the legitimate, normal path. This cuts down on extraneous supplies, and the overall amount of uncharged supplies. However, uncharged normal supplies actually increase because there are now more normal supplies period. Initial results indicate that even at low levels this methodology could make a noticeable impact.

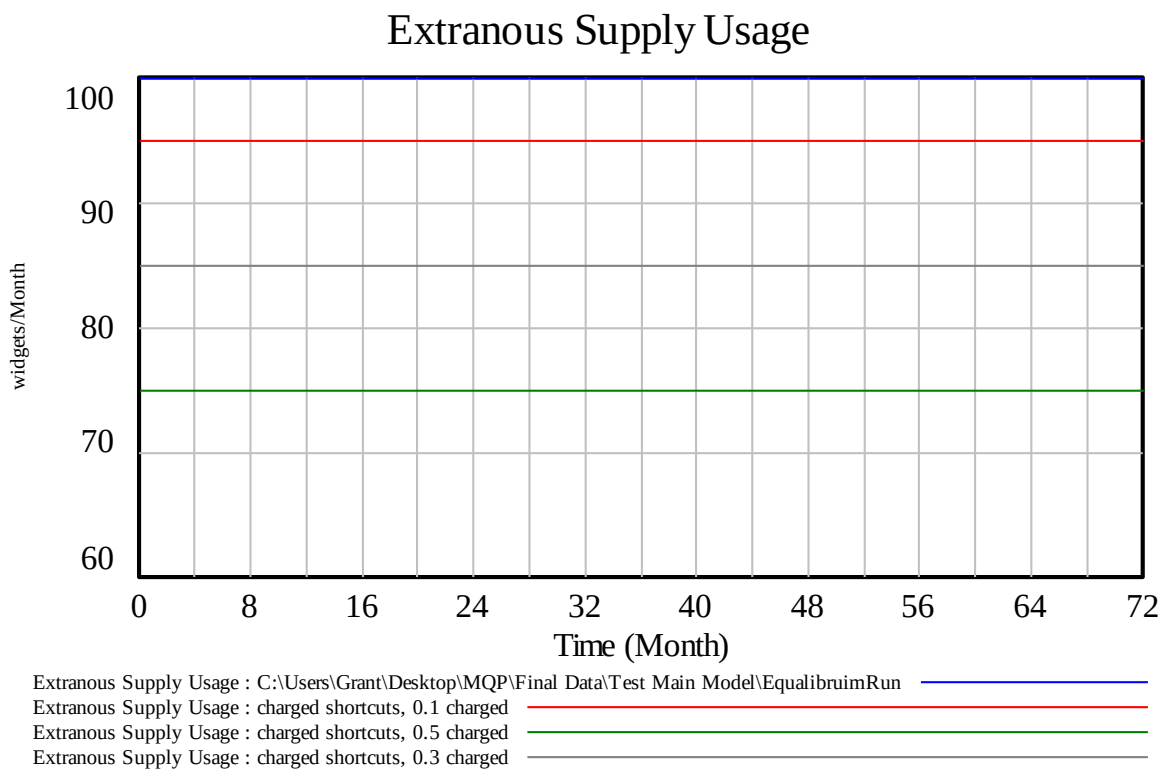

Figure 33: Legal shortcuts cut down on extraneous supplies

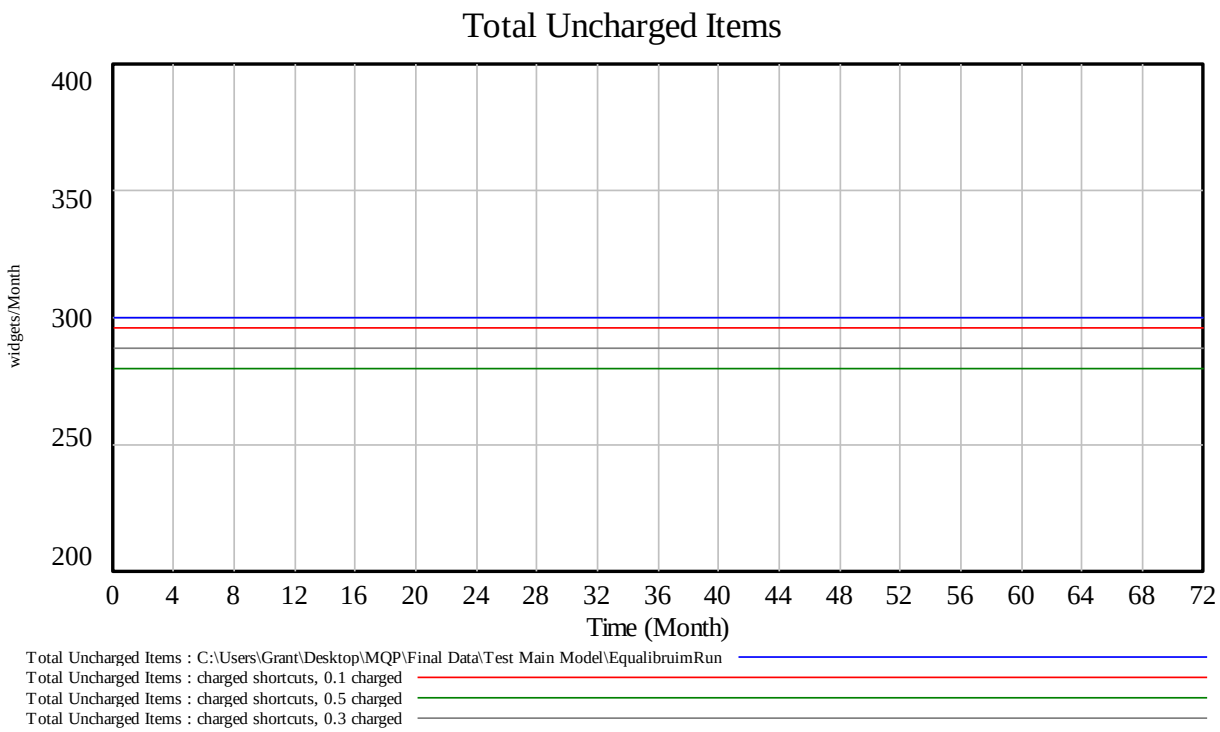

Figure 34: Total Uncharged Items Lower than Normal Model

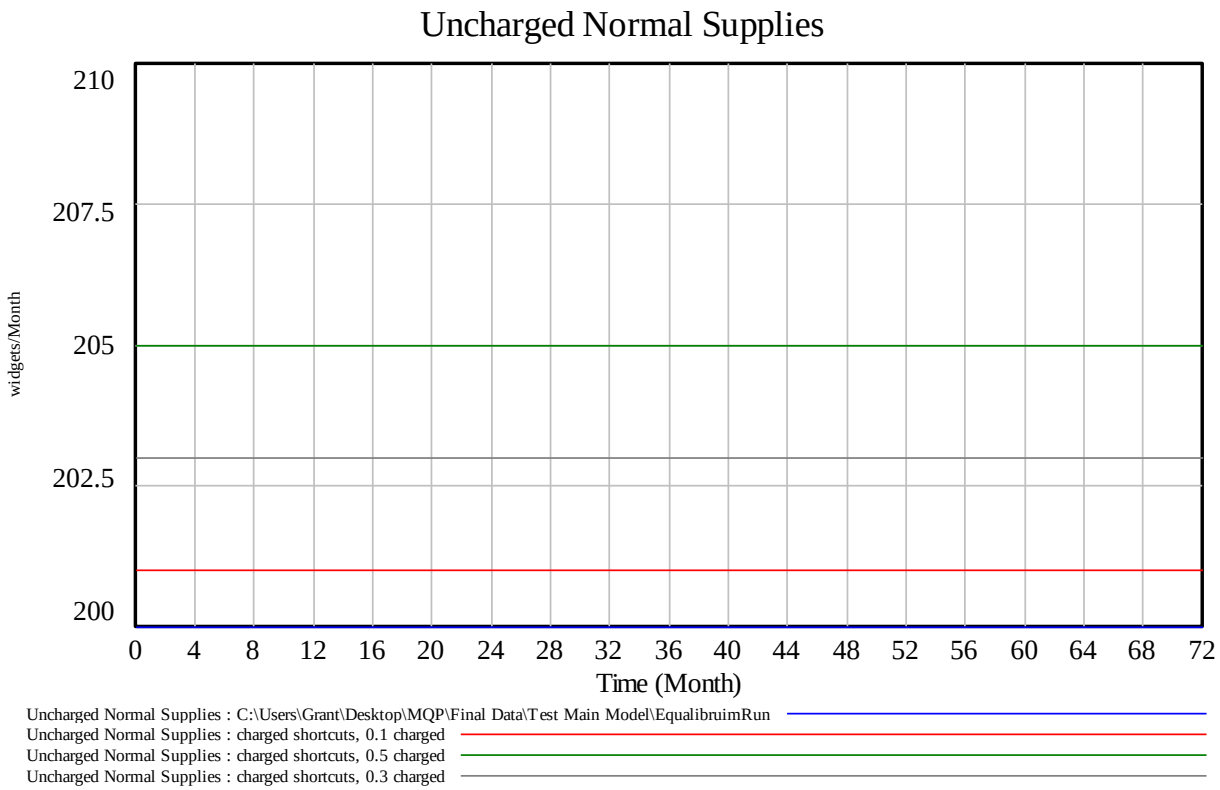

Figure 35 : Greater Normal Supplies means More will be Uncharged

4.5 Policy Recommendations and Insights

After developing the System Dynamics model for ECHN and establishing several scenarios, it became apparent that ECHN's nursing line problems could be solved at relatively low cost. The key for ECHN to make a long term impact is to find a way to keep nurses informed about the price of the items they are using and keep their awareness constantly high; a process which can be done relatively cheaply based on responses from the nursing. This process is best promoted with constant small reminders than occasional large meetings; an idea backed up by the nurses' themselves. One technique which may prove to be effective is to label items in the supply closets with the item's cost to the hospital, so nurses can see the value of an item regularly and understand its cost. Currently the items are unlabeled and therefore lack the ability to promote price awareness; if anything unlabelled items likely decrease the perception of value. An alternative could be a simple list of prices in the supply closest, with a list of key offending items and their value to the hospital. If this methodology isn't possible, then regular staff meetings need to include a supply based component to illustrate costs and their long term impact. Under worst case scenario conditions, such efforts would still create a change, just not as strong as ECHN would like to see.

The middle ground scenario provides a basis for establishing goals and determines that with the right policy and the current economic state then ECHN could see a major turnaround in as little as a year. Though as a precaution, efforts to educate the staff and increase their price awareness should remain in place even as the economy strengthens because of the

reduced effect of psychological safety. After all economic pressures likely account for some of ECHN's current progress.

Another element highlighted by the models was the lack of feedback present for ECHN. In the development of the model, many holes were unfilled by ECHN's own quantitative data, especially when pertaining to the underlying problems of the model. Many individual pieces of data are buried too deep for ready analysis. This missing data, if tracked by future incarnations of ECHN's own IS could be useful in furthering model refinement and in discovering new controls. In fact one of the greatest sources of data is readily available for ECHN; the nurses of the nursing lines know both their strengths and flaws quite well, readily pointing out the most commonly used shortcut items and explaining their own motivations. Such information could greatly benefit ECHN as a whole if shared.

Disposable Medical Supply Line Controls are entirely possible for ECHN to implement in a timely and efficient manner. With minimal effort, it is likely they could reduce supply usage to be only 2-3% over. With a longer term focus on breaking down the exact nature of their supply lines, they could possibly see results approaching near 0%, perhaps even applying lessons learned to other parts of the hospital.

Appendices

Appendix A: Variable List

Utilization ratio
Supply use rate
Supplies
Culture
Order volume
Supply expenditures
Departmental spending
Expenses
Sense of entitlement
Entitlements affect on spending
Union
Non-union
Seniority
Time to gain seniority
Acceptance of change
Training time
Rebellion against implemented policies
Cost saving initiative factor
Stress factor
Stress affect on want to cut corners
Supply card usage
Lack of accountability
Backtalk acceptability
Budget
Supply costs per person
Desired supply costs per person
Desired budget
Administrative time allotted
Education factor
Education training time
Effect of punitive action factor
Punitive action
Chaos factor
Economy worries
Ease of work
Improper use factor
Speed of work
Ease affect on work
Patient card usage
Patient care

Patient care quality
Worker bitterness
Management enforcement factor
Communication breakdown factor
Costs saved
Economic opportunity factor
Jobs at risk factor
Nurse overrun
Years of nursing service
Merit reward
Unionization factor ability to do job
Nurses
Supply widgets
Costs of supplies per widget
Perceived inequality
Nursing line inventory
Time spent reordering
Usage rate
Understanding of value of items used
Habit factor
Attitude factor
Technology
Overabundance usage
Average supply used per day
Patient request frequency
Perception of time away from patient's bedside.
Sticker Charges
Nurse Work Load

Appendix B: Nurse Interview Questions

ECHN Hospital Questions

1. Do you feel that patients ask for more supplies than they need? If yes, how frequently per work day do you feel this happens? Do you think these kinds of requests takes up unnecessary supplies for your patient unit?

2. How would you describe your own efforts to control supplies? Have you been educated on proper utilization of the different supplies?

3. Have you ever found yourself using supplies in unique, clever ways to save time? If so why and what?

4. If you had the option where you could select one of your daily tasks and only be responsible for that task, which task would you choose? If there was a responsibility you would like to drop, what would it be?

5. How big of a priority is supply management during your daily work routine. (Scale of 1 – 5)

6. What could be done to make hospital supplies easier to work with?

Note:
In this case supplies are defined as "disposable medical supplies".

Appendix C: Full ECHN Model Picture

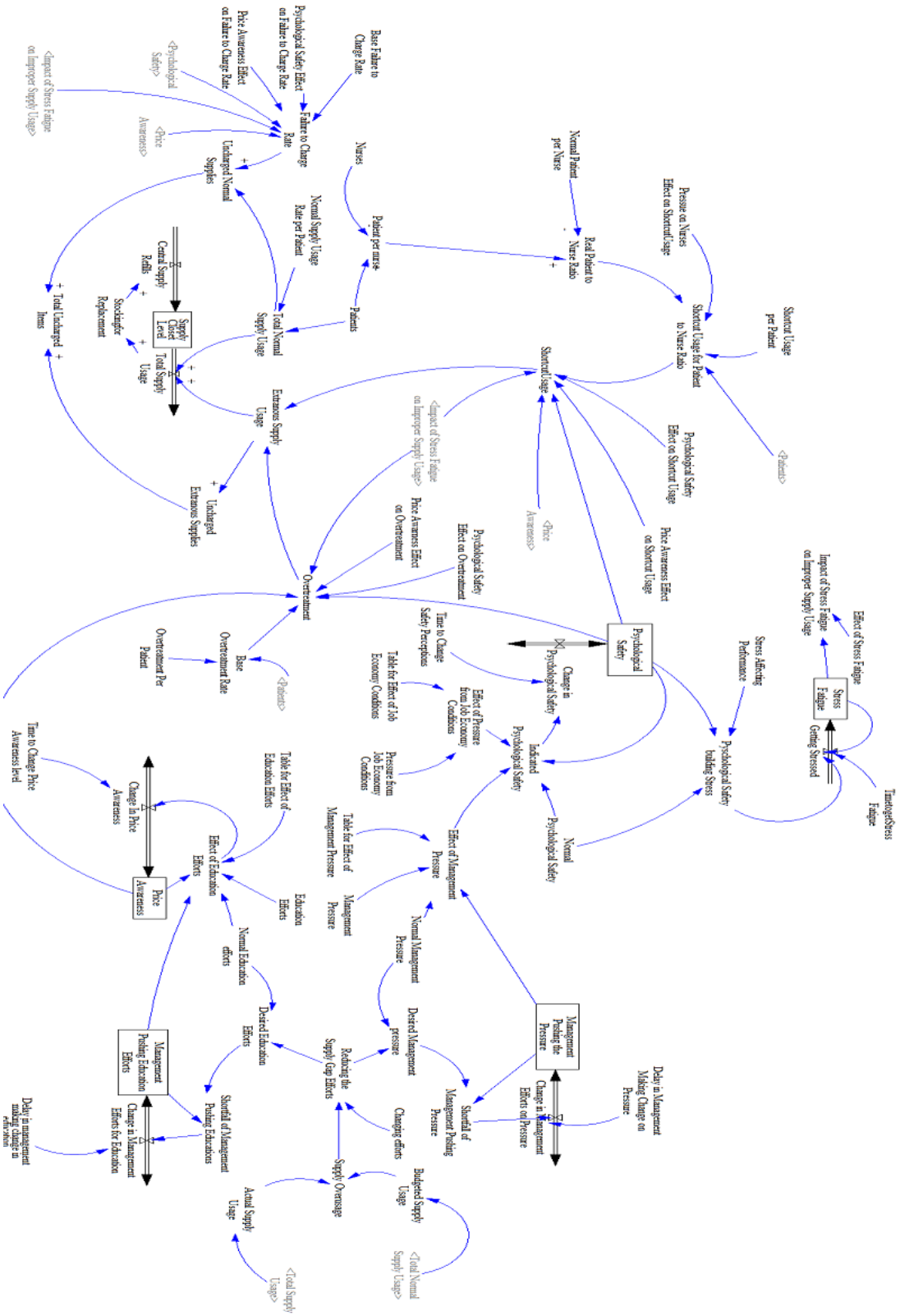

Figure 36: Full ECHN Model

Appendix D: ECHN Model Equations

Actual Supply Usage=Total Supply Usage
Units: widgets/Month

Base Failure to Charge Rate=0.2
Units: Fraction

Base Overtreatment Rate=Overtreatment Per Patient*Patients
Units: widgets/Month

Budgeted Supply Usage=Total Normal Supply Usage
Units: widgets/Month

Central Supply Refills=Stockingfor Replacement
Units: widgets/Month

Change in Management Efforts for Education=(Shortfall of Management Pushing Educations/Delay in management making change in education)*0
Units: hours/Month/Month

Change in Management Efforts on Pressure=(Shortfall of Management Pushing Pressure/Delay in Management Making Change on Pressure)*0
Units: Management Pressure Units/Month

Change In Price Awareness=Effect of Education Efforts/Time to Change Price Awareness level
Units: Education Units/Month

Change in Psychological Safety=Indicated Psychological Safety/Time to Change Safety Perceptions
Units: Safety Units/Month

Changing efforts([(0,-2)-(2.5,2.5)],(0,-1),(0.2,-0.8),(0.3,-0.6),(0.5,-0.4),(0.7,-0.2),(0.98
,0),(1,0),(1.02,0),(1.1,0.2),(1.2,0.4),(1.3,0.6),(1.5,0.8),(1.8,0.9),(2,0.95
),(2.2,1))
Units: Dmnl

Delay in management making change in education=4
Units: Month

Delay in Management Making Change on Pressure=4
Units: Month

Desired Education Efforts=Normal Education efforts*Reducing the Supply Gap Efforts
Units: hours/Month

Desired Management pressure=Normal Management Pressure*Reducing the Supply Gap Efforts
Units: Management Pressure Units

Education Efforts=8
Units: hours/Month

Effect of Education Efforts=MIN(10,Table for Effect of Education Efforts((Education Efforts+Management Pushing Education Efforts)/Normal Education efforts))-Price Awareness

Units: Education Units

Effect of Management Pressure=Table for Effect of Management Pressure((Management Pressure+Management Pushing the Pressure)/Normal Management Pressure)
Units: Dmnl

Effect of Pressure from Job Economy Conditions=Table for Effect of Job Economy Conditions(Pressure from Job Economy Conditions)
Units: Dmnl

Effect of Stress Fatigue([(-11,0)-(11,20)],(-10,1.2),(-5,1.05),(-3,1),(0,1),(1,1),(1.58104,0.868421),(3,0.8),(4,0.824561),(4.74312,0.903509),(5,1),(6,1.38596),(7.16514,1.47368),(7.83792,1.55263),(8.10703,1.58772),(8.10703,1.58772),(8.71254,1.62281),(9.31804,1.7),(9.58716,1.8),(10,1.9),(10.3945,2),(10.5291,2.1)
Units: Dmnl

Extraneous Supply Usage=Overtreatment+ShortcutUsage
Units: widgets/Month

Failure to Charge Rate=Base Failure to Charge Rate*Price Awareness Effect on Failure to Charge Rate (Price Awareness)*Psychological Safety Effect on Failure to Charge Rate(Psychological Safety)*Impact of Stress Fatigue on Improper Supply Usage
Units: Fraction

Getting Stressed=(Psychological Safety building Stress-Stress Fatigue)/TimetogetStress Fatigue
Units: Fraction/Month

Impact of Stress Fatigue on Improper Supply Usage= Effect of Stress Fatigue(Stress Fatigue)
Units: Fraction

Indicated Psychological Safety= MIN(10,Normal Psychological Safety*Effect of Management Pressure*Effect of Pressure from Job Economy Conditions)-Psychological Safety
Units: Safety Units

Management Pressure=5
Units: Management Pressure Units

Management Pushing Education Efforts= INTEG (Change in Management Efforts for Education, 0)
Units: hours/Month

Management Pushing the Pressure= INTEG (Change in Management Efforts on Pressure, 0)
Units: Management Pressure Units

Normal Education efforts=8
Units: hours/Month

Normal Management Pressure=5
Units: Management Pressure Units

Normal Patient per Nurse=10
Units: Patients/Nurses

Normal Psychological Safety=5

Units: Safety Units

Normal Supply Usage Rate per Patient=10
Units: widgets/Patients/Month

Nurses= 10
Units: Nurses

Overtreatment= Base Overtreatment Rate*Price Awareness Effect on Overtreatment(Price Awareness
)*Psychological Safety Effect on Overtreatment(Psychological Safety)*Impact of Stress Fatigue on Improper Supply
Usage
Units: widgets/Month

Overtreatment Per Patient= 0.5
Units: (widgets/Month)/Patients

Patient per nurse=Patients/Nurses
Units: Patients/Nurses

Patients=100
Units: Patients

Pressure on Nurses Effect on ShortcutUsage([(0,0)-
(3,3)],(0,0),(0.25,0.3),(0.5,0.5),(0.75,0.75),(1,1),(1.16208,1.35965
),(1.25382,1.75439),(1.5,2),(1.8,2.3),(2,2.4),(2.5,2.5))
Units: Dmnl

Pressure from Job Economy Conditions=5
Units: Fraction

Price Awareness= INTEG (Change In Price Awareness,
5)
Units: Education Units

Price Awareness Effect on Failure to Charge Rate([(-0.1,0)-
(10,10)],(0,3),(1,2.7),(2,2.5),(3,2),(4,1.5),(5,1),(6,0.75),(7,0.5
),(8,0.3),(9,0.2),(10,0.05))
Units: Dmnl

Price Awareness Effect on Shortcut Usage([(-0.1,0)-(10,10)],(0,2),(1,1.8),(2,1.6),(3,1.4),(4,1.2),(5,1),(6,0.85),(7
,0.6),(8,0.4),(9,0.3),(10,0.2))
Units: Dmnl

Price Awareness Effect on Overtreatment([(-0.1,0)-(10,10)],(0,2),(1,1.8),(2,1.6),(3,1.4),(4,1.2),(5,1),(6,0.85),(7
,0.6),(8,0.4),(9,0.3),(10,0.2))
Units: Dmnl

Psychological Safety= INTEG (Change in Psychological Safety,
Normal Psychological Safety)
Units: Safety Units

Psychological Safety Effect on Failure to Charge Rate([(0,0)-
(10,2)],(0,0.5),(1,0.6),(2,0.7),(3,0.8),(4,0.9),(5,1),(6,1.1),(7,1.2

),(8,1.3),(9,1.5),(10,1.7))
Units: Dmnl

Psychological Safety Effect on Overtreatment([(0,0)-(10,2)],(0,0.5),(1,0.6),(2,0.7),(3,0.8),(4,0.9),(5,1),(6,1.1),(7,1.2
),(8,1.3),(9,1.5),(10,1.7))
Units: Dmnl

Psychological Safety Effect on Shortcut Usage([(0,0)-(10,2)],(0,0.6),(1,0.65),(2,0.7),(3,0.8),(4,0.9),(5,1),(6,1.1),(7,1.2
),(8,1.3),(9,1.5),(10,1.7))
Units: Dmnl

Psychological Safety building Stress=Stress Affecting Performance(Psychological Safety/Normal Psychological
Safety
)
Units: Fraction

Real Patient to Nurse Ratio=Patient per nurse/Normal Patient per Nurse
Units: Dmnl

Reducing the Supply Gap Efforts=Changing efforts(Supply Overusage)
Units: Fraction

Shortcut Usage for Patient to Nurse Ratio=Shortcut Usage per Patient*Patients*Pressure on Nurses Effect on
ShortcutUsage
(Real Patient to Nurse Ratio)
Units: widgets/Month

Shortcut Usage per Patient=0.5
Units: (widgets/Month)/Patients

ShortcutUsage=Shortcut Usage for Patient to Nurse Ratio*Price Awareness Effect on Shortcut Usage
(Price Awareness)*Psychological Safety Effect on Shortcut Usage
(Psychological Safety)*Impact of Stress Fatigue on Improper Supply Usage
Units: widgets/Month

Shortfall of Management Pushing Educations=Desired Education Efforts-Management Pushing Education Efforts
Units: hours/Month

Shortfall of Management Pushing Pressure= Desired Management pressure-Management Pushing the Pressure
Units: Management Pressure Units

Stockingfor Replacement= Total Supply Usage
Units: widgets/Month

Stress Affecting Performance([(0,-20)-(4,10)],(0,10),(0.152905,6.666),(0.452599,3),(0.85,0),(1,0),(1.15
,0),(1.57187,-3),(1.85933,-6.666),(2,-10),(2.2,-11))
Units: Dmnl

Stress Fatigue= INTEG (Getting Stressed,0)
Units: Fraction

Supply Closet Level= INTEG (+Central Supply Refills-Total Supply Usage,1000)
Units: widgets

Supply Overusage=Actual Supply Usage/Budgeted Supply Usage
Units: Fraction

Table for Effect of Education Efforts([(0,0)-(4,10)],(0,0),(0.2,1),(0.4,2),(0.6,3),(0.8,4),(1,5),(1.2,6),(1.4,7)
,(1.6,8),(1.8,9),(2,10))
Units: Education Units

Table for Effect of Job Economy Conditions([(0,0)-(10,2)],(0,1.8),(1,1.75),(2,1.65),(3,1.45),(4,1.25),(5,1),(6,0.75),
(7,0.55),(8,0.35),(9,0.25),(10,0.2))
Units: Fraction

Table for Effect of Management Pressure([(0,0)-(2,2)],(0,2),(0.2,1.95),(0.4,1.85),(0.6,1.65),(0.8,1.35),(1,1),(1.2
,0.65),(1.4,0.35),(1.6,0.15),(1.8,0.05),(2,0))
Units: Dmnl

Time to Change Price Awareness level=3
Units: Month

Time to Change Safety Perceptions=3
Units: Month

TimetogetStress Fatigue= 3
Units: Month

Total Normal Supply Usage=Patients*Normal Supply Usage Rate per Patient
Units: widgets/Month

Total Supply Usage=Extraneous Supply Usage+Total Normal Supply Usage
Units: widgets/Month

Total Uncharged Items=Uncharged Extraneous Supplies+Uncharged Normal Supplies
Units: widgets/Month

Uncharged Extraneous Supplies=Extraneous Supply Usage
Units: widgets/Month

Uncharged Normal Supplies=Total Normal Supply Usage*Failure to Charge Rate
Units: widgets/Month

Appendix E: Other Scenarios Model (Changes to original structure only)

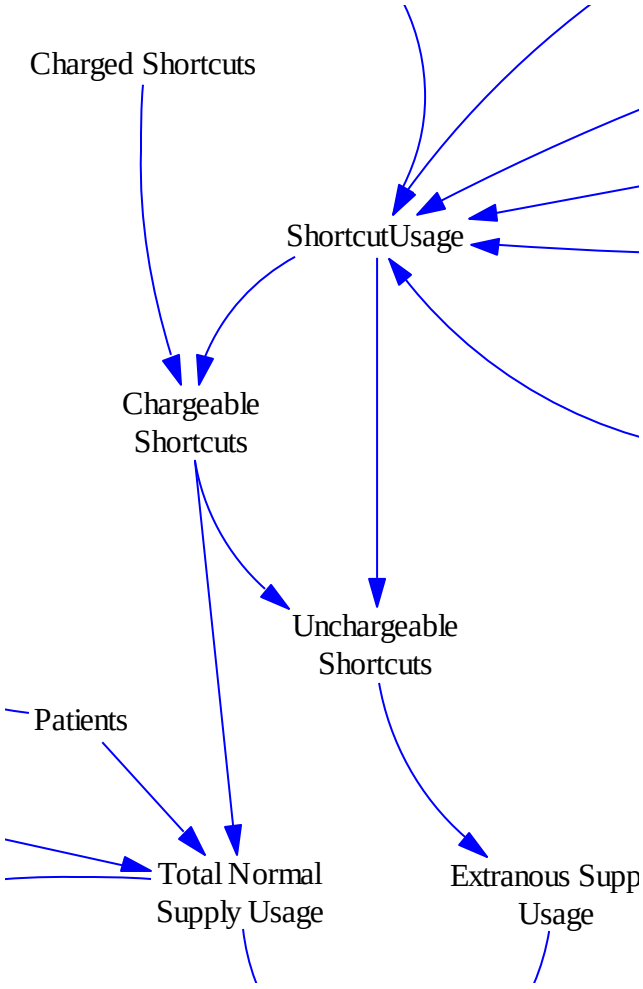

Figure 37 Shortcut Usage Changes for Other Scenario models

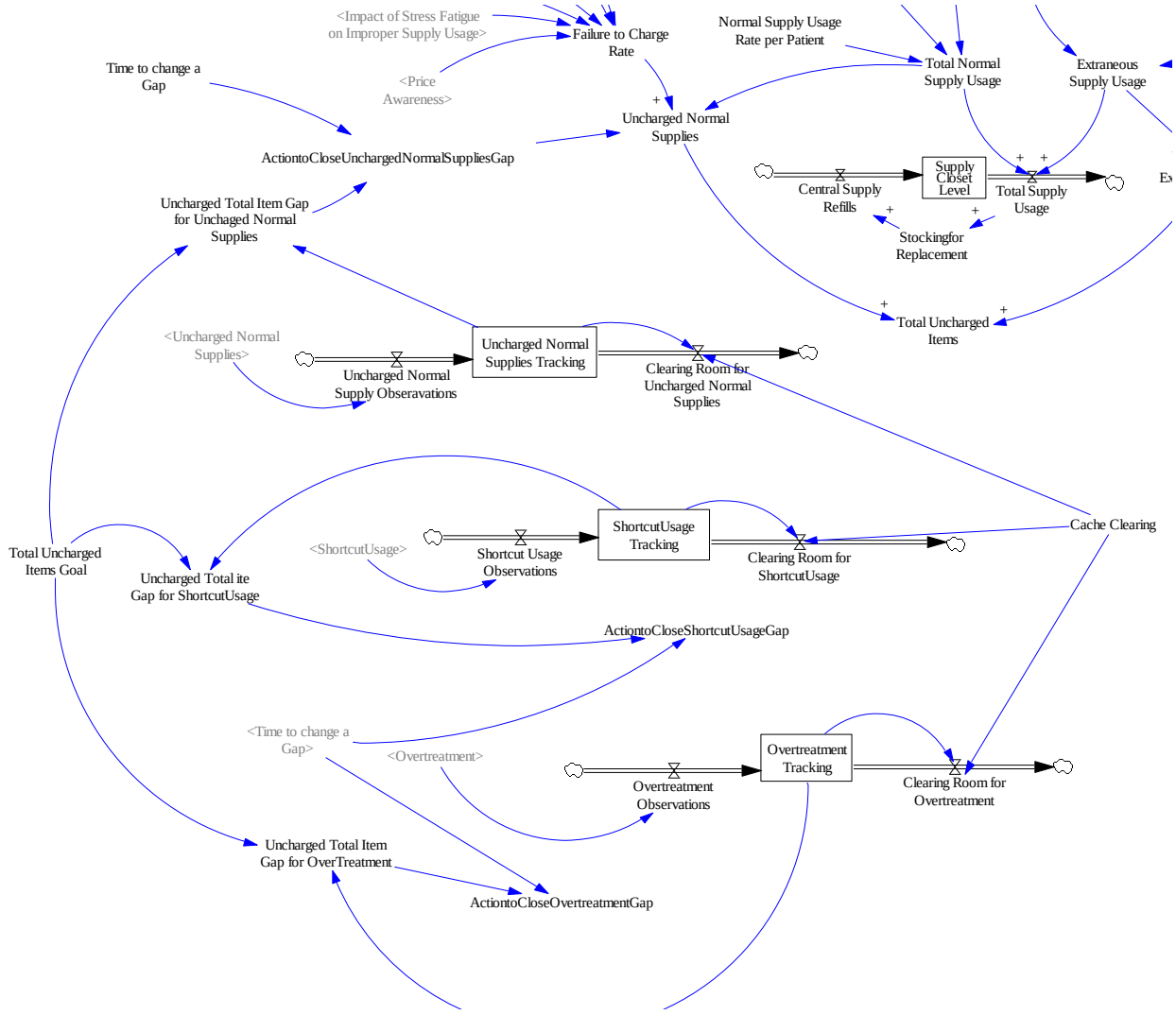

Figure 38 : Main Body of Additions for IS Efforts and Example Control

Appendix F: Other Scenarios Model Equations (Changes only to original structure only)

Appendix F.A: Shortcut Charging

Chargeable Shortcuts=Charged Shortcuts*ShortcutUsage
Units: widgets/Month

Charged Shortcuts=0.3
Units: Fraction

Extraneous Supply Usage=Overtreatment+Unchargeable Shortcuts
Units: widgets/Month

Patients=100

Units: Patients

ShortcutUsage=Shortcut Usage for Patient to Nurse Ratio*Price Awareness Effect on Shortcut Usage (Price Awareness)*Psychological Safety Effect on Shortcut Usage (Psychological Safety)*Impact of Stress Fatigue on Improper Supply Usage
Units: widgets/Month

Total Normal Supply Usage= (Patients*Normal Supply Usage Rate per Patient)+Chargeable Shortcuts
Units: widgets/Month

Unchargeable Shortcuts=ShortcutUsage-Chargeable Shortcuts
Units: widgets/Month

Appendix F.B: New IS

ActiontoCloseOvertreatmentGap=Uncharged Total Item Gap for OverTreatment/Time to change a Gap
Units: widgets/Month

ActiontoCloseShortcutUsageGap=Uncharged Total Item Gap for ShortcutUsage/Time to change a Gap
Units: widgets/months

ActiontoCloseUnchargedNormalSuppliesGap=Uncharged Total Item Gap for Unchaged Normal Supplies/Time to change a Gap
Units: widgets/Month

Cache Clearing=5
Units: Month

Clearing Room for Overtreatment=Overtreatment Tracking/Cache Clearing
Units: widgets/months

Clearing Room for ShortcutUsage=ShortcutUsage Tracking*Cache Clearing
Units: widgets/Month

Clearing Room for Uncharged Normal Supplies=Uncharged Normal Supplies Tracking/Cache Clearing
Units: widgets/Month

Overtreatment=(Base Overtreatment Rate*Price Awareness Effect on Overtreatment(Price Awareness)*Psychological Safety Effect on Overtreatment
(Psychological Safety)*Impact of Stress Fatigue on Improper Supply Usage)+ActiontoCloseOvertreatmentGap
Units: widgets/Month

Overtreatment Observations=Overtreatment
Units: widgets/Month

Overtreatment Tracking= INTEG (Overtreatment Observations-Clearing Room for Overtreatment,50)
Units: widgets

Shortcut Usage Observations=ShortcutUsage
Units: widgets/Month

ShortcutUsage=(Shortcut Usage for Patient to Nurse Ratio*Price Awareness Effect on Shortcut Usage(Price Awareness)*Psychological Safety Effect on Shortcut Usage(Psychological Safety)*Impact of Stress Fatigue on Improper Supply Usage)+ActiontoCloseShortcutUsageGap
Units: widgets/Month

ShortcutUsage Tracking= INTEG (Shortcut Usage Observations-Clearing Room for ShortcutUsage,50)
Units: widgets

Time to change a Gap=2
Units: months

Total Uncharged Items=Uncharged Extraneous Supplies+Uncharged Normal Supplies
Units: widgets/Month

Total Uncharged Items Goal=0
Units: widgets

Uncharged Normal Supplies=(Total Normal Supply Usage*Failure to Charge Rate)+ActiontoCloseUnchargedNormalSuppliesGap
Units: widgets/Month

Uncharged Normal Supplies Tracking= INTEG (Uncharged Normal Supply Observations-Clearing Room for Uncharged Normal Supplies,200)
Units: widgets

Uncharged Normal Supply Observations=Uncharged Normal Supplies
Units: widgets/Month

Uncharged Total item Gap for ShortcutUsage=Total Uncharged Items Goal-ShortcutUsage Tracking
Units: widgets

Uncharged Total Item Gap for OverTreatment=Total Uncharged Items Goal-Overtreatment Tracking
Units: widgets

Uncharged Total Item Gap for Unchaged Normal Supplies=Total Uncharged Items Goal-Uncharged Normal Supplies Tracking
Units: widgets

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