A Systems Approach to Reducing Utility Billing Errors

By

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Submitted to the MIT Sloan School of Management and the Engineering Systems Division on May 10, 2013 in Partial Fulfillment of the Requirements for the Degrees of Master of Business Administration and Master of Science in Engineering Systems

Abstract

Many methods for analyzing the possibility of errors are practiced by organizations who are concerned about safety and error prevention. However, in situations where the error occurrence is random and difficult to track, the rate of errors at a particular instant in time is not a practical metric of hazardous conditions (or whether a system may be vulnerable to errors). Qualitative indicators (such as stress levels) that are easier to observe, but difficult to measure, may be linked to the dynamic behavior of quantitative indicators that are easier to measure using System Dynamics models. In this work, we propose a method to find an appropriate metric for error analysis, by determining the direct quantitative triggers associated with the qualitative indicators of hazardous conditions. A System Dynamics model is generated for determining the measurable quantitative indicator behaviors linked to more apparent qualitative factors for determining the health of a system. Used in concert with other system methodologies, it gives insight into triggers and policies for developing and implementing improvement processes.

The context of this research is in reducing billing errors at a utility company which for confidentiality reasons we refer to as United Energy. We use several system methodologies including System Dynamics and Safety System Analysis, to assess the billing operation system and process, to develop a project management plan for the development and implementation of a tool to reduce billing errors.

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To my family, it goes without saying, but will be said anyways - Thank you for your constant listening, encouragement, and support. To my other family of LGO 13's: being able to talk through and discuss our projects has definitely been an experience of sharing best learning.

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Note on Information Disguise

The research presented in this thesis uses information from an internship project in partnership with a utility company. In order to protect confidential sensitive information, the company name will be disguised and referred to as United Energy throughout this thesis.

1. Introduction

1.1 Thesis Hypothesis

The research presented in this thesis is part of an internship project for the Leaders of Global Operations program at the Massachusetts Institute of Technology in partnership with the electric and gas utility company which we refer to throughout this work as United Energy. The purpose of this thesis is to demonstrate that System Dynamics modeling can be used for the often difficult identification of quantitative assessment metrics for the hazard state of a system for error prevention. Furthermore, System Dynamics in conjunction with other systems methodologies can be used through an entire improvement process from problem diagnosis to product management and development, to ultimately impact qualitative factors such as work stress. The advantages of using systems methodologies will be discussed, and the background of company project at United Energy will be given to provide the context of the problem.

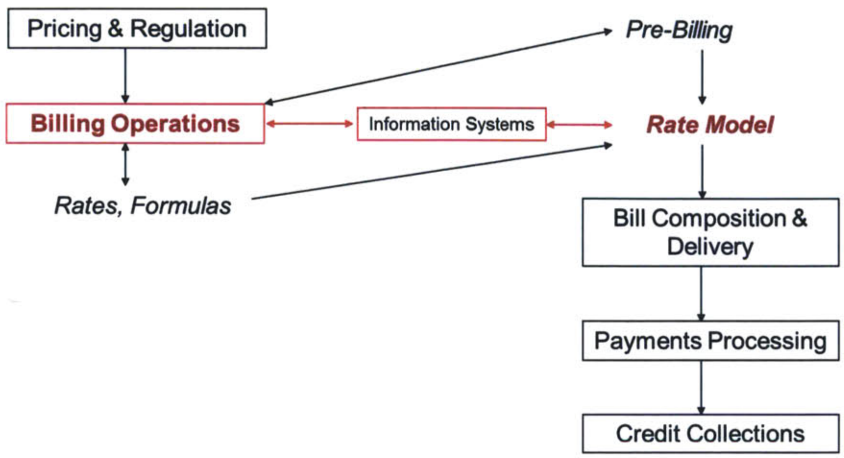
1.2 Project Background: United Energy Motivation to Reduce Errors

United Energy is a UK based utility company that operates in the US east coast. Services include power generation, and electricity and gas deliveries, which includes transmission as well as distribution to commercial and residential customers. Several mergers and acquisitions over the past 15 years have required the integration of different regional systems, adding to the complexity of the organization and its operations. From 2002 to 2007, United Energy acquired 2 companies, increasing its gas distribution network in Rhode Island (See [5]). The company culture and structure of United Energy is affected by such acquisitions by requiring additional coordination work to address issues of complexity, organization, and visibility. With services to about 3.3 million electric and 3.4 million gas customers, United Energy sends out millions of utility bills to its customers on a monthly basis (See [16]).

Limited personnel resources, added to the complexity of the organization and processes, are underlying causes for billing errors which affects United Energy's overall public image. Public confidence has been voiced as being a primary concern, which affects the outcomes of rate cases where United Energy requires government approval to modify its price charges. A companywide improvement process named "Meter-to-Cash Initiative," has been started in 2012 to address the customer service concerns, through the use of consultant interviewing of various employees, and round table discussions. The ultimate goal of United Energy is to increase customer satisfaction by reducing billing errors at United Energy. This project spun off from the momentum generated by the Meter-to-Cash initiative, specifically focuses on the Billing Group which is at the core of the Meter-to-Cash process, with accountability for error mitigation response, and the critical area for integrating the inputs to the billing model for bill generation.

The Billing Operations group at United Energy coordinates changes to the Billing Rate model, integrating price and volume information from several departments of the company. Billing errors fall under the responsibility of the often stressed 16 person Billing operations group of tariff model analysts. As shown in Fig. 1, these analysts have to interface with several different groups to make changes to the complex billing model, which consists of a very complicated program that was originally created in 1984 in COBOL. This model has grown increasingly complex with the addition of different types of accounts and complex pricing formulas which the Billing Analysts may interact with through a database consisting of hundreds of tables and thousands of parameters. For the Billing Analysts, this has contributed greatly to the difficulty of their responsibility of ordering the changes to the bill model, and its verification. The job is so complex that it takes about a year of training before an analyst can begin to make modeling changes. When errors occur during billing, thousands of accounts may be affected. The impact of these errors is next described.

Figure 1: Meter to Cash Process



The Billing Operations group is at the center of the Billing group, interacting group in the "Meter to Cash" Process

Error Impacts

Errors are discovered sometimes by customers, but internal mitigation reports show that many errors are found internally by the billing analysts while making changes to the model and during verification. In terms of United Energy customer impacts, an error can result in over bills or under bills. When United Energy becomes aware of an error, it either makes adjustments to the next bill, or sends out an additional corrected bill. In the end, an unknown error may cost the customer, but if United Energy knows of a significant billing error, it will correct the bill. Billing errors although corrected, may be an indicator of operational issues that impact the customer in the long run through operational costs.

In terms of United Energy impacts, the error effects are not "costly" in the usual sense as for non-regulated industries, because they do not reduce profits directly. United Energy is shielded from the competitive stresses that private enterprises have to face, because as a utility, once a rate case is accepted, it has a legally established rate of return (See [6]). While costs for processing possible rebills and rework costs may be large in size, and may be used as indicators for error impact, they are not a concern from a monetary perspective, but rather on how errors effect their perception by the governmental regulators who make the decisions on rate cases. The other concern for United Energy is in the actual operational impacts, such as work load of the analysts, and stress. As shown previously in Figure 1, Billing Operations is at the intersection of other group inputs from Pricing and Regulation and Meter Data Services (which is a part of Pre-Billing). Error mitigation reports from the past two years were compiled and analyzed as errors generated from the 3 groups, from the cost perspectives described above in Figure 2. Temporary impacts to customers may be viewed from an accuracy perspective in terms of Net Overbill and Underbill.

Figure 2: Error Impact over past 2 years

	Error Percentage	Net Overbill/Underbill	Rebill Costs	Rework Costs
Pricing & Regulations	20%	$555K	$0.1K	23 days
Billing Operations	60%	$3M	$520K	222 days
Meter Data Services	20%	$3.6M	$590K	62 days

From an operations perspective, the costliest impact for United Energy was actually the rework costs which resulted in about 222 days being lost over the last 2 years. It is understandable that the Billing Operations Group who is responsible for integration of the inputs and changes to the complex Billing Model work, has the highest frequency of errors, and takes the longest to recover from an error. The frequency of error generation effects United Energy's relationship with regulatory agencies, and impacts its operational efficiency. In terms of temporary customer impacts, Meter Data Services has large impacts, and it is recommended that it too be considered. This project centers on errors that are generated from the work of the Billing Operations group at

United Energy, and reduction of time consuming rework. The project motivation in the larger scope of process improvement policies with system engineering methodologies is next explored.

1.3 The Systems Motivation: Addressing Macro Issues and Complex Problems

The use of systems engineering methodologies is used to analyze the interactions between the components of the complex systems. Hughes describes the emergence of systems engineering from the demand for management coordination with the heterogeneous nature of the 1950s Atlas Project in the development of the first inter-continental ballistic missile (See [2]).
Systems engineering was later adopted by NASA to coordinate the complex Apollo projects of the 1960s which similarly to United Energy, had great project complexity issues with the integration of the work of many suppliers and contractors (See [2]). With a systems view point, managerial policies have effectively addressed technical problems, such as the enforcement of rigid cleanliness standards and methods for reducing the defects in rocketry production (See [3]). Since United Energy's billing process itself is complex, and involves complex interactions between many entities, a systems approach is taken in this work to find an overall metric to target for improvement, and to aid in the general design for an improvement process.

The problem of a proper metric for error or accident prevention is evidenced by the number of methods developed over the years to analyze the possibility of errors. The systematic operations management method of lean six-sigma, has developed from an environment where production is in such large quantities and at such a high rate, so that defects although produced at a low percentage, are still statistically able to be measured and characterized. Where the types of errors can be characterized consistently, it is possible to use the actual rate of error as a metric for the health of a system's operation. However, when the processes of a system are not standardized, errors may be much more random, and may occur at a lower rate, thus making it difficult to assess and then prevent. In such cases, the rate of error produced during real life measurements may not be an accurate indicator of the present health of a system. Over a long duration, it may be possible to measure error statistically, but that is hardly practical for immediate assessment of a policy for error prevention. How does one measure the absence of errors, or measure how well something is not happening? Because of a lack of metric for error feedback, a policy may not be immediately recognized as contributing towards hazardous conditions, and an effective error prevention policy may not receive the support it is worthy of. Qualitative indicators such as stress or confusion are easier to observe but not easy to measure, thus a way to link the qualitative to quantitative indicators would be helpful. Such a tool exists in System Dynamics, which we use to find direct quantitative triggers to or from qualitative indicators of hazard conditions. In this project a System Dynamics model is used in concert with other system methodologies to not only give insight into triggers and policies for creating an improvement process, but also to provide insight into what quantitative indicator behaviors to analyze in determining whether the system is moving toward healthy or hazardous conditions.

1.4 Contributions of the Thesis

The purpose of this thesis is to analyze a complex business problem, more specifically United Energy's complex billing process, with a systems approach using System Dynamics on the macro level to generate recommendations for a policy to influence the conditions that lead to error generation. In a larger context this could be applied to other organizations where processes for error reduction are required. The systems approach includes a response using Safety Systems specified towards process gaps, rather than responding to individual errors, to aid in United Energy's operational processes. This analysis has led to development of a tool to address the needs of United Energy to train its Billing analysts and reduce Billing errors. The procedures and characteristics of the tool need not be specific to United Energy, but can be applied toward other tools to visualize complex models as well.

Thesis Contributions:

1. Systems methodology for Complex Process Improvements
    - Systems Dynamics- for determining quantitative metrics and drivers
    - Safety Systems- for targeting specific process improvements
2. Model Visualization Tool for United Energy
    - Comprehensive understanding of bill model – to sharpen the learning curve/competency of Billing Analysts
    - Verification tooling and process improvements to increase efficiency and accuracy in Billing – to reduce Billing Errors

The Billing analysts' needs for their work in bill modeling addressed specifically by the tool are the issues of increasing model organization and visibility for the training of the analysts of a wide range of experiences. Understanding the content of enormous databases such as customer accounts and their interrelationship such as through a billing model is a challenge for any company which provides individualized services to millions of customers. The visualization techniques and characteristics suitable for displaying and explaining database information and its interrelationships, as well as process steps for changing the database are incorporated into a tool for training analysts. For United Energy, this bill model visualization training tool contributes to improving the Billing analysts' mental models of the complex billing model which is critical for the prevention of errors.

1.4 The Thesis Structure

Chapter 1 introduces the project motivations for reducing Billing Errors at United Energy and the need for systems approaches for macro policy and process improvements.

Chapter 2 discusses the use of System Dynamics for determining quantitative metrics for feedback as well as triggers for macro policies.

Chapter3 contains an analysis using the Safety Systems approach to target process improvements.

Chapter4 discusses the design and development of Tool for Visualizing the Bill model.

Chapter 5 reviews Conclusions and Recommendations of the project.

2. System Dynamics view of Macro Issues

This portion looks at the Macro Issues of a business strategy for prevention of errors. Qualitative business approaches have been linked to quantitative ideas such as Complex Adaptive Systems approach to identify risks and potential consequences of business decisions (See [7,13]). The problem of a proper metric for hazard conditions is approached here by using System Dynamics to link qualitative triggers to the behavior of quantitative metrics, to help create an appropriate management plan for United Energy to reduce unwanted billing errors.

2.1 Why System Dynamics?

The modeling technique created by Jay Forrester at MIT allows one to analyze behaviors through interactions of factors and their effects quantitatively over time, dynamically. The ability to model complex interactions dynamically makes System Dynamics a valuable tool in providing both short term and long term effects. The implications are often surprising because complex interactions are difficult to conceptualize (See [8]). In addition models offer the chance to analyze various situations that are not testable because of time limitations, factors out of the control of the experiment, and/or because of ethics. It is often during just the setup of the model, where flaws in the dynamic hypothesis are revealed which help to improve overall understanding of the system (See [8]).

System Dynamics has the innate capability to link the quantitative with the qualitative:

> "It is suggested that within studies the true power of system dynamics to address problem solving lies in a judicious blend and intertwining of both qualitative and quantitative ideas, aimed at addressing as broad an audience as possible whilst remaining sufficiently rigorous to be useful. Within organizations it is suggested that there is a need to cement together the use of qualitative system dynamics in management development and quantitative system dynamics modeling for strategic and operational learning in teams." (See [4])

Thus it is useful as a tool to improve the understanding of how an organization's performance is related to dependent factors influenced by its structure and operating policies, and then to use that understanding to design high leverage policies for success. (See [8])

2.2 Literature Review: Previous System Dynamics Models

Current System Dynamics models include those on the effects of reinforcing feedback such as with network effects in the increasing spread and adoption of new products modeled with the Bass Diffusion Model. Modeling of added work load and resource effects has also been used to characterize the difficulty of adoption of new processes (See [8,p. 189, 766-772)]). In general, for the adoption of a new process which requires additional work, additional resources are required for a process to be learned and to become a permanent fixture. A System Dynamics analysis for process improvement is tailored to United Energy billing operations.

2.3 A System Dynamics Overview of United Energy & its Billing Process

In a System Dynamics model, various factors trigger a reaction of effects and when it feeds back on itself in a loop, the net effect can be either reinforcing where the net influence is positive feedback over time, or balancing where the net influence is negative feedback over time. Various feedback loops affecting the generation of errors in United Energy's billing process are shown in Fig. 3. The model includes the feedback behavior of: B1) Billing Analyst Fire-fighting work (balancing feedback), R2) Rework or errors (reinforcing feedback), R3) Added Coordinating and Verification Work (reinforcing feedback), as well as R4) Inter-group Coordination and Verification Capabilities (balancing feedback). The dominance of particular feedback loops will produce often completely different scenarios. The 4 feedback behaviors and how United Energy's particular characteristics influence the behavioral loops are described below. The interaction of the different feedback behaviors is given in context for a specific example of a United Power billing error called "YQ/YR Charge type error".

Billing Error Example- The YQ-YR Error

To give an idea of how an error may occur, and its implications, we have tracked an example of an error which occurred on 3/1/2010 in Billing Operations; identified as "YQ/YR Error." A new type of charge was added for some bill accounts. The error occurred when in adding the charges to the model, required parameters were not changed in a related table. The omission of one line in a table impacted approximately 600 customers. 1786 individual credit adjustments were deemed necessary. During the error mitigation process, in an attempt to fix the problem, additional mistakes were made when the new charges were accidentally added to another charge causing them to be considered twice. It took about 3 months to completely address the problems, analyze the affected accounts, and correctly readjust the affected bills.

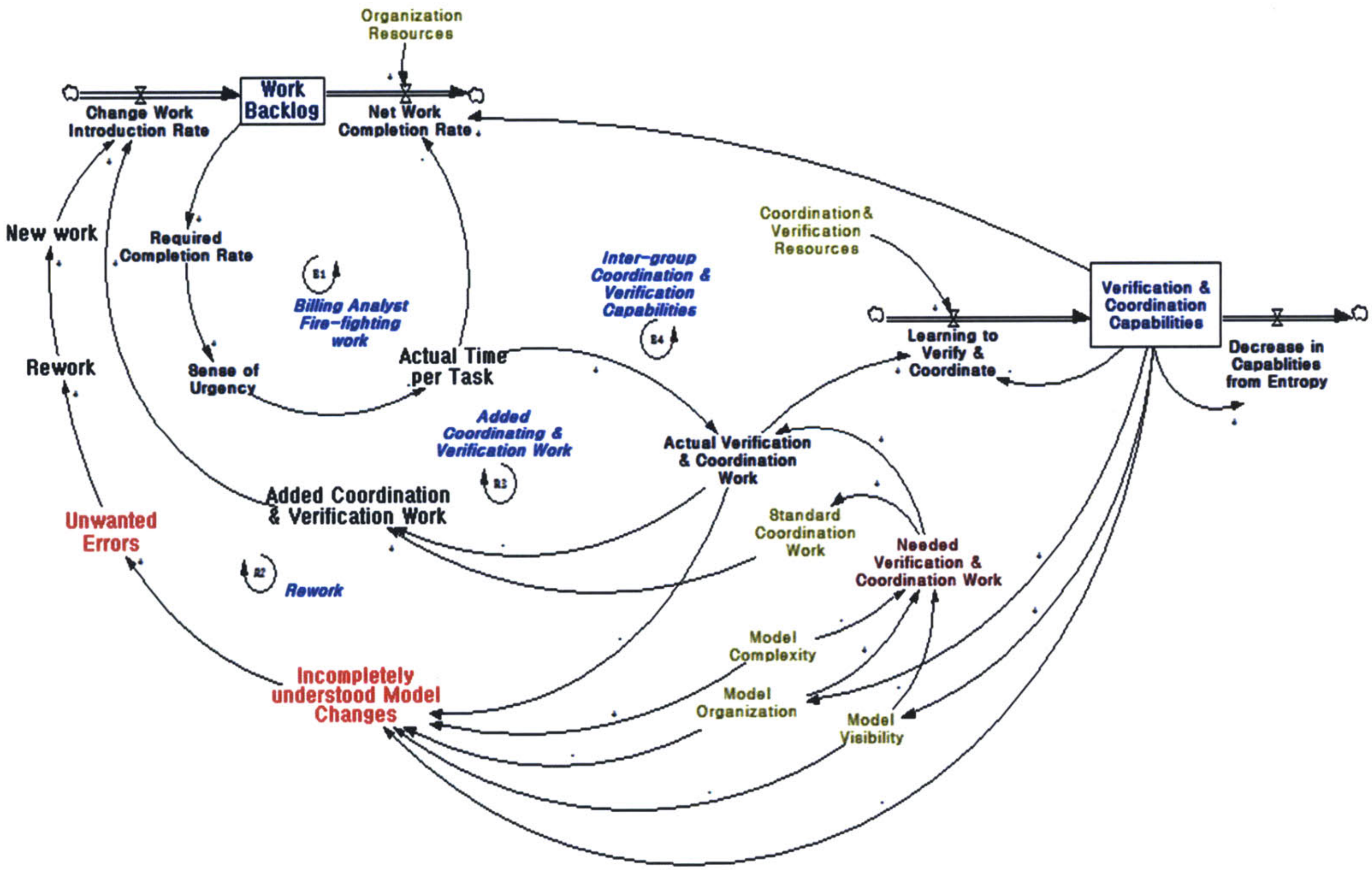
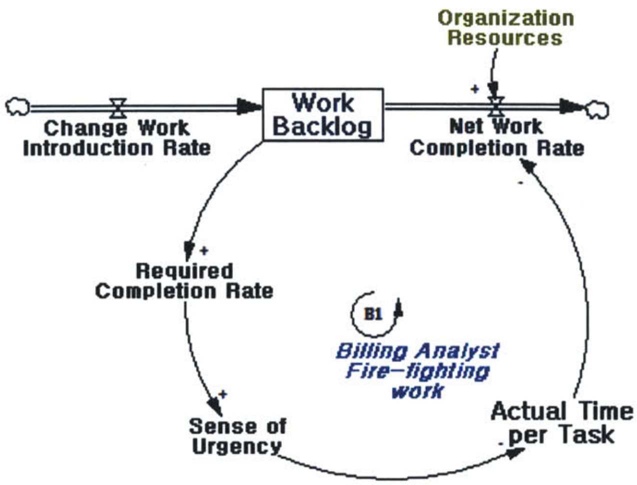


Figure 3: System Dynamics Model of Billing Errors at United Energy

Figure 4: B1) The Billing Analyst Firefighting Work Balancing Feedback Loop

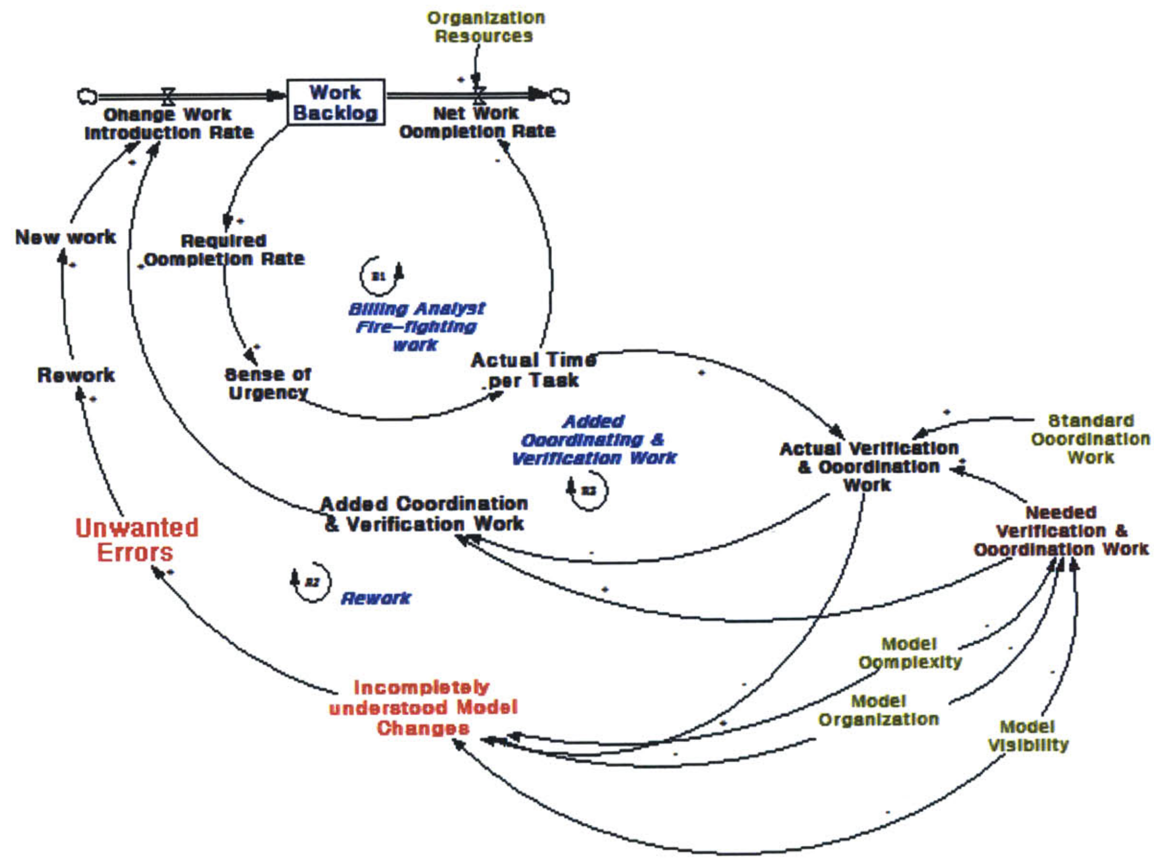


B1) The Billing Analyst Firefighting Work Balancing Feedback Loop:

The Firefighting Work balancing feedback loop is an important main driver of work behavior that needs be considered. This condition as described by analysts where the "YQ/YR Error" occurred is stressful, but is not a behavior at all unique to United Energy. It happens when an organization's work force is pressured to keep up with a large work load. When a work introduction rate is dramatically increased in comparison to the Net Work completion rate, a sudden increase in work back log occurs, which increases the required completion rate, increasing the sense of urgency, and decreasing the actual time spent per task, driving toward an increase in completion rate in order to reduce the work back log. The organizational resources performing the work consist of a small group of analysts challenged to keep up with the frequent changes to the complicated rate model. Often they are responsible for a complicated task which involves many procedures to follow.

For Billing Analysts, this includes coordinating input from different company groups, interpretation of a model change, and verification of the model change. When time is constrained in relation to work load of the task, an analyst will have less time to work on all the steps for a model change task, which has direct implications on the other behavioral feedback loops.

Figure 5: Added Coordination and Verification Work, and Rework Loops



<u>R3) Added Verification Reinforcing Feedback Loop</u>

The Billing Operations analysts have the challenge of coordinating information and work between different company agencies such as Pricing and Regulation and an outsourced Information Services group. The analyst's task of changing the rate model is always new, and it is difficult to standardize or know the implications for a brand new change. The work has to be verified as well which involves checking sample account bills. The actual Verification and Coordination work that is done by an analyst represents a certain percentage of the work done in a task. Therefore, the larger the actual time per task available, the more completely Coordination and Verification can occur for the task (bill change). The more Verification and Coordination work defined as standard, the more added work is introduced, which feeds into the analysts firefighting balancing loop by increasing the work load. Needed Coordination and Verification work is directly influenced by the process steps and complexity of the model which involves a large amount of tables and interrelated parameters.

Billing Error Example- Verification

The conditions, during which the YQ/YR Charge type error occurred, had verification and coordination work that depended greatly on the skill of the Billing analyst and their network of information. Analysts often seek the help of other analysts to review their change, and ask clarifying questions to their counterparts in Information Services as well as Pricing and Regulation. However, there was little standardization in this verification and coordination loop. The YQ/YR Charge type error was made by a Billing analyst who had worked less than a few months on Bill model changes. This person once having made that error, always made sure to check the table and parameter that had not been correctly changed, but prior to that model change had not known about the importance of that particular parameter check in the table which was not correctly changed. This underlies the importance of bringing the expert know-how to the inexperienced analyst without having to make the analyst learn through making costly errors.

R2) The Rework Reinforcing Feedback Loop:

Errors caused by an incompletely understood modeling change, as mentioned earlier have negative impacts on workload, customer confidence, and United Energy's relationship with government agencies. All these error effects may be reduced if this rework loop is made as insignificant as possible. The more time per task, the more actual coordination and verification can occur, decreasing the modeling changes that are incompletely understood, which decreases the number of unwanted errors, in turn decreasing the amount of rework which is necessary to both redo the original change and fix the negatively impacted accounts. We see that the importance of reducing the loop is so critical because when errors do occur, causing additional workloads to be given, this feeds back into the firefighting Loop, where the analysts are even more stressed and take less time to confirm a change. This feeds back again into the rework loop, so that errors can lead to a higher probability of more errors which has been observed to happen in historical error mitigation reports.

Billing Error Example- Rework

Interestingly enough, the YQ/YR Charge error contributed to the balancing reinforcing feedback loop of creating more work with the introduction of more errors in fixing the problem on the already stressed Billing analyst group. New charges were accidentally added to another charge causing them to be accidentally considered twice. While the error was an important learning experience for the new modeling analyst, it was particularly painful in terms of effort and time. The analysis of the problem and the bill adjustments took about 3 months to complete, and undermined other required modeling work.

B4) Inter-group Coordination and Verification Capabilities

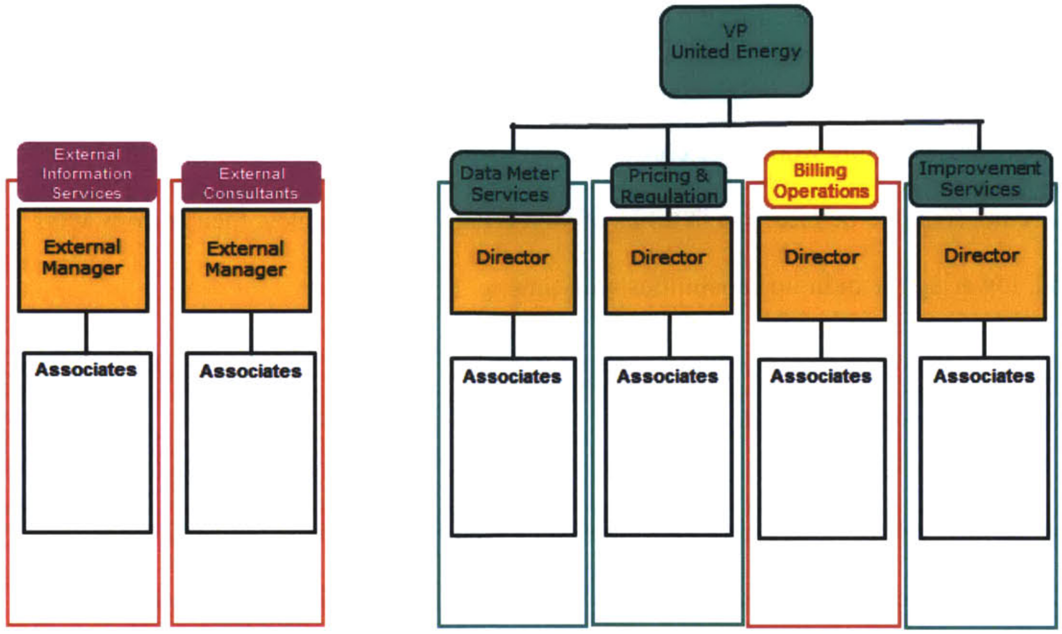
Over time, analysts build up capabilities which allow them to be able to perform the tasks more efficiently, increasing the Net Work completion rate, and lowering the amount of work backlog. Thus far, the behavioral fire-fighting loop was the only loop which seeks to lower the work load by increasing the work rate. Unfortunately, the consequences of decreasing the actual time per task in such a way may actual increase the work load in the long run, because the work is less efficient when it is not coordinated and verified adequately. The increase in the work efficiency by Coordination and Verification Capabilities, maintains Coordination and Verification levels in the task time so that the rework loop is unaffected. The more work that is done, the higher the rate of learning is, which builds up analyst Verification and Coordination Capabilities. This affects the billing process in two ways, it increases the rate at which work is done, and also decreases the likelihood of incompletely understood modeling changes and errors. This is not a permanent state, however. Sadly, entropy works as a constant drain on these capabilities, and when the capabilities are not found to be effective in terms of increasing work efficiency, then entropy wins out in the end, lowering the built up capabilities with time.

2.4 Policy effects on the Behaviors:

The organizational structure, culture, and viewpoints at United Energy affect the way work is coordinated, which was collected through interviews with analysts and personal observation. Because of the high level of expertise required for the process steps in the entire Meter to Cash process, each of the groups in United Energy are silo-ed (Figure 7), with functional specialties. This however, has led to internal processes within groups and their effects to become less visible. The Billing Operations group role is in charge of model modifications and the error mitigation process, and has to interface with many of these groups by necessity. Unfortunately, the groups they interface with do not always understand the needs of the Billing Operations group, and the information Billing Operation receives is sometimes incomplete or inaccurate. This makes coordination and verification an even more critical requirement of any model change.

The Billing group itself, holds the greatest accountability for errors, but since they do not make the actual change to the model, they are highly dependent on the external consultant Information Service group which changes the model for the Billings analysts (Figure 1). There is a history of relying on strong inter-personal relationships for day to day problem-solving and conflict resolution.

Figure 6: Formal structure of Organization - Silos



Verification of information by a Billing Analyst requires a good personal relationship with their counterparts in the other groups and relies on the expertise of all sides. If an expert is lost on either of the sides, and the process changes, there is often a gap in the information that is passed, increasing the likelihood of errors. There is a high reliance on the analyst experts, who over many years have an excellent mental model of the bill model and understand the implications and areas affected by a bill change. The System Dynamics model of an expert has a high level of verification and coordination capabilities built up over many years of experience, with high net work completion rates, and comprehensive understanding of the model, so that the firefighting work and inter group coordination and verification capabilities loops dominate. The experts are usually given the most complicated bill changes, and build up even more verification capabilities. One can look at the System Dynamics model at time 0 before an analyst has built up expertise. In this case, a new analyst has not built up the verification and coordination capabilities which may take years to understand the model. Until the capability is built up, an inexperienced analyst makes incompletely understood model changes and unwanted errors, with the firefighting work and rework loops dominating until the verification and coordination capabilities build up slowly till the inter group coordination and verification capabilities dominate over the rework loop. With the experts having so much capability and the difficulty of new analysts to build up the capabilities, there is a tendency to rely on the experts more heavily, and the new analysts take even more time to gain capabilities.

The System Dynamics model points out several levers for decreasing the unwanted errors. First of all, incompletely understood model changes is shown as the driver for the errors, which is influenced by the time spent doing verification and coordination work, the model characteristics (complexity, organization, visibility), and the capabilities of the analyst. These 3 levers will be discussed for possible policies for error reduction.

Increasing Actual Verification and Coordination Work

If the analysts spend more time for verification and coordination work during a task, they will make less incompletely understood model changes. If standards are increased however, there is added work, and as shown in earlier modeling examples, this presents the problem of getting over the learning hump, with extra work, there is a drive for analysts to not do the verification work when they are work stressed. Solutions often involve an influx of organizational resources to increase the time available per task, so that verification and coordination experience have a chance to be built up. It is important to note that just increasing organization resources without increasing standards, may decrease work load and lower the unwanted errors in the short term. However, if actual verification and coordination work is not kept at a constant high rate, then learning and verification capabilities cannot be built up to prevent errors in the long run.

Verification and Coordination work leading to capabilities which increase efficiency, lowering work backlog are immediately valuable, allowing for more actual and verification work to be accomplished, with quicker adoption of the work. Some work capabilities are less about efficiency and more about increasing the comprehension of the model. While in the long run, this saves an analyst time from doing rework, the short term effects of added work may work against the adoption of the capability. If the addition of organizational resources is not sufficient to allow for greater levels of actual verification and coordination work, then other ways for increasing net work completion rate, such as a tool for verification or coordination is necessary in conjunction to the capabilities.

The model characteristics itself should not be neglected as levers into incompletely understood model changes. Capabilities and work can be increased to handle the complexities of the model, its organization and visibility. If the model is increasingly growing more complex, and structural issues make the model less visible, then increasing pressure is put on the analysts to do more verification work and increase their capabilities. The most powerful lever is to decrease the model complexity, and increase organization and visibility which additionally makes it easier to set high Standards for coordination, requires less verification and coordination work, and decreases the chance of incompletely understood model changes.

2.5 Addressing the Billing Error Problem – Improvement Policy Characteristics

The System Dynamics model gives us clues to management policies for an error reduction improvement process, and the important combinations of levers to consider. Policies directed at alleviating the symptoms of a problem often fail because of the unintended triggering of feedbacks. (See [8, p.189])

> "Policy design … includes the creation of entirely new strategies, structures, and decision rules. Since the feedback structure of a system determines its dynamics, most of the time high leverage policies will involve changing the dominant feedback loops by redesigning the stock and flow structure, eliminating time delays, changing the flow and quality of information available at key decision points, or fundamentally reinventing the decision processes of the actors in the system." (See [8, p.103 -104])

First of all, the problem of a metric for measuring unwanted errors is addressed by tying the qualitative metric of incompletely understood model changes to its quantitative input of Actual time spent on Verification and Coordination Work. For an analysis of the effectiveness of new initiatives, this metric is easy to measure by asking analysts how much extra time was spent on the new tool or procedure. The actual value may not matter as much as the trend of the time spent on the tool to indicate whether the tool was being adopted, and thus the efficacy of the tool. The increase may be due to the pressure of an increase in the Standard Coordination work, but if that is optional which was true in our prototyping phase, then any actual added voluntary work is indicative of a perceived value in the tool or procedure.

The System Dynamics model indicated that in order to reduce errors, the actual verification and coordination work performed should be increased to build up the verification and coordination capabilities for the long term prevention of errors and increased work efficiency. For this to happen a number of things are required. First, the Standards for Coordination Work should be increased as a driver for increasing the level of Actual verification and coordination work. The Net Work Completion rate also needs to be increased so there is less pressure on the analysts and they have time to learn the new verification and coordination work. These conditions favorable to learning the verification and coordination capabilities need to be held for a period of time so that the verification and coordination capabilities are built up to a point where the analyst is able to work more efficiently and effectively. This learning phase is critical for the adoption of new techniques or tools, which must be shown to be effective otherwise, the initiative will fail to be adopted for the long term. Initiatives to increase the verification and coordination work may be abandoned or even increase unwanted errors if they add additional work without the benefits of work efficiency and accuracy being seen. This could be just due to the time required in the training and effects of the improvement process to be seen, or the ineffectiveness of the tool or process improvement. In order for the learning hump to decrease in time and magnitude, and for the analysts to build up their verification and coordination capabilities more quickly, the actual verification and coordination work should increase during the learning phase. Standards may need to be increased in order to drive the improvement initiative if analysts do not perceive the immediate value in the processes.

The silo structures between groups and individualized work procedures have been pointed out as barriers to sharing information and training. Billing Analysts will have to have greater visibility into the actual model (IT area), and drive standardization of documentation procedural/hand off standards, as well as training. Structurally, more bridges between the silos could be implemented through tooling and documents with inter-silo information, to enable visibility between groups.

In order for the project outcome to be accepted for the long term, the implementation of the solution needs to have involvement from the key stakeholders of the Billing Operations group, with the flexibility to allow the individual to analyze, verify, and make improvements themselves.

The internship project addresses the Macro challenge of the functional silos with cross group communications through standardized handoff documentations that coordinate the work and address the needs of the individual groups. The micro challenges of the reliance of the expertise of analysts, and individualized procedural improvements are addressed by procedural improvements/preserving best shared practices, through tooling for verification and robust standardized documentation and procedures. Because of the silo structure between the groups, the timing and goals of each group are not always aligned with the overall goal of customer satisfaction and error minimization. If the processes and requirements of each group have greater visibility, then the interests may gain greater alignment, with cooperative handoffs.

The silo structure and hierarchical politics of United Energy has influenced an individualized culture which relies highly on personal relationships as avenues for information exchange. The need for metrics for feedback to the Billing Operations, as well as methods for preserving and sharing best-practices is a goal of the project, which requires coordination across silos through tooling and standardized inter-group documentation. The development of which, requires involvement of the Billing analysts throughout. For the long term, the Billing analysts have to maintain the project tools and information, which needs to be accessible to change by the analysts themselves.

3 A Safety Systems Analysis of Billing Operations

While the System Dynamics model identifies the macro triggers and suggests policies for error reduction management, a Safety System approach may be implemented to identify the particular areas in the process for targeting specific improvements.

3.1 Safety System for Targeting Process Improvements

Current strategies for reducing failures include traditional fault tree analysis, which prioritizes hazards based on the probability of error, impact of error, and frequency of occurrence. However, as many examples of failures attest, the probability of an error happening is not entirely accurate, because the probability of an error is considered zero until it actually happens, with impacts unknown until they actually occur. It is often a "special" combination of the conditions which lead to unforeseen errors. The Safety System approach is well-suited for a technique to reduce errors, and has been used "to reduce risk is to anticipate accidents and their causes in before-the-fact hazard analyses (rather than relying on after-the-fact accident investigations) and to eliminate accidents or to reduce the consequences."(See [9, p.13])

In order to address the project target to reduce Billing errors, and improve efficiency and accuracy of model changes, the current Billing processes are assessed for improvement suggestions.

3.2 Literature Review: Previous Safety System Analyses

Several previous accidents have been analyzed by Nancy Leveson, to illustrate the methods for safety system analysis and the formation of recommendations (See [9]). The Apollo 13 accident is an example where traditional probabilistic failure analysis could not predict the accident.

> "Nobody believed such a quadruple failure could occur – independence had been assumed incorrectly. This belief lead to a failure to take account of what was considered a low–probability event: Nobody thought the spacecraft could lose two fuel cells and two oxygen tanks. In addition, contingency plans had been drawn up for using the lunar module in an emergency, but had never been practiced in the simulator." (See [9, p.562-563])

In another study, the chemical plant accident of Icmesa Chemical Company owned by Swiss company Givaudan, severely affected the adjoining highly populated community of Seveso. An accidental increase in temperature and pressure in the reactor producing trichlorophenol produced the toxic byproduct dioxin. (See [9, p.584]) While the tendency often lies in putting the responsibility on the operators during the time of the accident, the causal factors for Seveso were found through Safety Systems analysis to be in the cultural and political macro issues of complacency and discounting risk and competing priorities. In terms of process issues, causal factors were training, uncommunicated and unreviewed changes, superficial and ineffective safety measures such as alarms and interlocks with no warning of high temperature or other type of signaling or shutdown equipment (See [9,p.590]) Through studies of all possible errors, the system requirements, and the hazard conditions , a more complete root causal analysis can be made for preventing failures in complex systems that support the System Dynamics policy analysis.

3.3 Hazards, Systems, Requirements

The Billing Operations procedures are analyzed as a system for hazard conditions, in the Safety System Analysis recommended by Leveson. The "accident" that may occur in this case is that the customer is charged an incorrect amount (overbill or under bill error). The hazard conditions that allow accidents or errors to occur are listed below. Furthermore, the hazard conditions allow us to develop System level constraints for the prevention of the hazard conditions.

High-level system hazard conditions:

- United Energy inputs into the Billing process are not accurate, or on time
- United Energy systems for Billing process break down, delayed, or act disjointedly
- Environment of billing where insufficient time or resources are given
- (Ex: regulators expect immediate implementation of change)

System-level constraints:

- All Systems (including people) must have the resources to perform the tasks they are responsible for in a timely manner
- All Systems must interact in a way to perform tasks for the ultimate goal of accurate and timely Billing
- All Systems must not be stressed for extended periods of time or other conditions which lead to hazardous state
- **Monitoring of Systems (includes system members, automated system based on key metrics) to report hazardous conditions (Detection of danger indicators, Ex: Verify Batch process)**
- Proper and timely response for in danger/certain hazardous conditions
- Proper and timely response by Systems affected by incidents (Ex: Billing Mitigation Plans)

This systems level view is maintained with the question of whether these requirements of Billing Operations are being met throughout the analyses of the specific billing processes. In analyzing the Billing process through historical errors and interviews with the analysts, we question whether the systems have the resources need to perform the tasks, and whether the systems are interacting effectively, and whether there is a metric to report hazardous conditions. The tool that was built for the Billing analysts, may not address all the constraints, but should address a need in these areas. For example, a Visualization tool may address the resources need for training and understanding of the model. A standardized process handoff, may address the need for efficient interactions between systems. Additionally, a verification procedure may address the monitoring of systems to report hazardous conditions. The detailed billing change process is assessed to determine the need addressed, and the tool response for the Billing analysts.

3.4 Billing Rate Change Process – Inputs/Outputs

A Safety Systems analysis is performed on more specific processes of a change to the bill model by Billing Operations. The complete billing process is analyzed to understand the types of errors that occur, the primary causes, and their effects. This has required numerous interviews with the Billing group and the other groups it interfaces with, in order to understand the inputs to and outputs from the Billing Operations group which is documented in Figure 8.

In the analysis, a matrix with possible errors for each process step is created and historical errors are mapped onto the billing process (Figure 9). Error impacts are quantified and improvement focus areas are recommended. The critical area within the Billing Operations processes has been narrowed to model change interpretation, and a tool for model mapping is offered as a solution. Additionally, a change verification tool is recommended for the prevention of the hazard conditions.

Figure 8 very simplistically maps the Billing Change procedure into the 4 processes described below, which occur in the sequence given and may be iterative as additional modifications to a change request are found necessary.

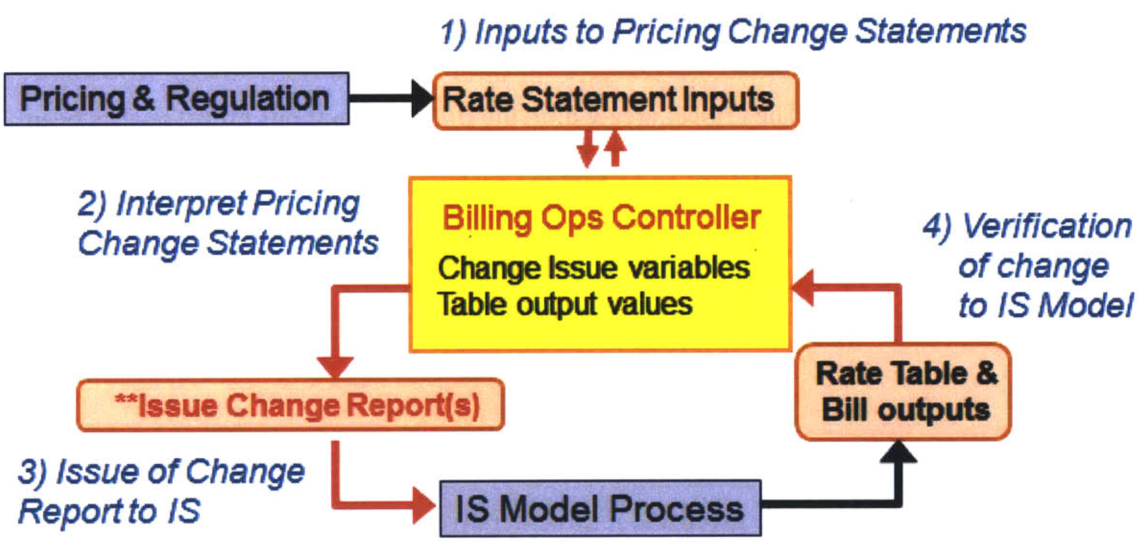
1) **Inputs to Pricing Change Statements:**
   The Billing operations group receives a change request from Pricing and Regulation. Often this is internally driven and may be in the format of a series of email exchanges.
2) **Interpret Pricing Change Statements:**
   The pricing change is interpreted by Billing Operations analysts in terms of the model parameters and tables. This relies on the expertise of the analyst and their mental model of the bill model to understand the implications of a bill change.
3) **Issue of Change Report to IS (Information Services):**
   The model changes are reported to IS in terms of a worksheet called an STS report.

The IS has an internal change report called an ITT report. The IS people then make the actual change to the model in a test environment.

4) **Verification of change to IS model**

The analysts query the test environment, pulling off parameter values from database tables. These values are confirmed against an excel spreadsheet of charges that are applied to a set of accounts with one sample account for each of the tariff types that are expected to change. These valued excel synopsis are the result of years of modeling verification.

Figure 7: Billing Process



3.5 Matrix of Possible Errors

In a Safety System approach to the modeling change described above, it is possible for an error or failure to occur at any of these 4 procedures or control actions. An error matrix is created for these procedures in Figure 9, for all the possible errors, in order to catalog the hazards comprehensively, and then review the hazard levels.

An error can occur where:

1) The control action is not provided
2) The control action is provided
3) There is a wrong timing or order of the control action
4) Control action is stopped too soon

Figure 8: Matrix of Possible Errors in Bill Change Process

In Billing Operations

Improve by Process
Improve by Model/Tool

Control Action	1) Not providing Control Action causes hazard	2) Providing Control Action causes hazard	3) Wrong Timing or Order of Control Action	4) Control Action Stopped too soon
1) Inputs to Pricing Change Statement	Change signal is ignored by Billing	Inputs are wrong or incomplete	Work not completed in time for Effective date	Incomplete Changes Communicated
2) Interpret Pricing Change Statement	Interpretation is wrong or incomplete	Interpretation is wrong or incomplete	Work not completed in time for Effective date	Incomplete Changes Communicated
3) Issue of Change Report to IS	Change signal is ignored by IS	Interpretation is wrong or incomplete	Work not completed in time for Effective date	Incomplete and/or inaccurate change requirements
4) Verification of IS Modeling Change	Errors are not identified	Incorrect verification causes errors	Work is incomplete, not accurate	Incomplete Verification, errors fall through cracks

The hazard conditions which produce the errors for the control action are listed in the matrix in Figure 8. These can be categorized in terms of process issues such as unstandardized procedures and handoffs which violate the technical constraint mentioned earlier:

- Decision making must be based on correct, complete, and up-to-date information,

As well as model interpretations which have the potential to violate the technical constraint below:

- Decision making must include transparent and explicit consideration of accuracy concerns

3.6 Error History Analysis

Historical Errors may not be an accurate predictor of future occurrences of errors, but historical patterns may give an idea of what processes should be targeted for improvements. Historical Errors from actual internal documentation of Mitigation Reports over the last two years were plotted on to the matrix of possible errors in Figure 9. They were found to be randomly distributed over the matrix, meaning that all areas were good candidates for improvement areas. It also suggests that all the control actions could benefit from standardization of process steps. Two major steps stood out however in the control actions: 2) interpretation of Pricing Change Statement & 4) Verification of the IS modeling changes.

Figure 9: Error Matrix with Historical Occurrences

Historical Errors In Billing Operations
Past 2 years ●

Improve by Process
Improve by Model/Tool

Control Action	1) Not providing Control Action causes hazard	2) Providing Control Action causes hazard	3) Wrong Timing or Order of Control Action	4) Control Action Stopped too soon
1) Inputs to Pricing Change Statement	Change signal is ignored by Billing ●	Inputs are wrong or incomplete	Work not completed in time for Effective date ●	Incomplete Changes Communicated
2) Interpret Pricing Change Statement	Interpretation is wrong or incomplete ●	Interpretation is wrong or incomplete ●	Work not completed in time for Effective date ●	Incomplete Changes Communicated
3) Issue of Change Report to IS	Change signal is ignored by IS ●	Interpretation is wrong or incomplete ●	Work not completed in time for Effective date ●	Incomplete and/or inaccurate change requirements
4) Verification of IS Modeling Change	Errors are not identified ●	Incorrect verification causes errors ●	Work is incomplete, not accurate ●	Incomplete Verification, errors fall through cracks ●

2) Interpret Pricing Change Statement process is highly dependent on analysts expertise level due to the complexity of the model; requiring a good mental model.

Billing Error Example

The YQ/YR errors are an example of an historical error occurring in the 2) Interpret Pricing Change Statement process, where the interpretation by a Billing analyst was incomplete. The Billing analyst did not understand the full scope of a bill model change, thus the errors were passed on to the order for a model change in control action 3). Additionally, the verification by the analyst in control action 4) missed the error because the verification of the model checked the model change against the Billing analyst's concept of the model, and not the accuracy of the Billing analyst's mental model. Upstream errors are passed on through the entire process and are highly dependent on the expertise of the analysts and are therefore difficult to address.

4) Verification of IS Modeling change is a downstream process and could potentially catch many errors upstream, so it would be a valuable for catching and fixing errors. There is however, a more robust verification program in development at United Energy already.

3.7 System Recommendations for Improvement Focus Areas

The process we decided to focus on was the upstream process of helping the analyst with the interpretation of the pricing change statement (control action process 2), with correct mental models of the bill model change. This is one of the more challenging system constraints because the bill model is so complex, and because of the silo structure macro concerns that make learning the model the most difficult verification and coordination capability. The procedure map of Figure 7 displays the process map whereby the Billing Operation analysts receive inputs from the Data Meter Services and Information Services. Although the actual changes to the model are made by the Information Services group, the Billing Operation analysts are in charge of the change request and the verification of the changes. Outsourcing the model changes to Information Services may have been necessary, but the error potential may be increased because of the effects on model visibility. Actually eliminating some of the analysts' tasks can make it more difficult for the analyst "to receive the feedback necessary to maintain an accurate model of the system." (See [9, p.123]) It makes model change verification a difficult task for the billing analysts when the change is made by an outsourced party which is not held responsible for verification checks on its own changes.

An analyst's understanding of the bill model is however at the core of the process, and the System Dynamics model analysis of policies for error prevention showed that building up of verification and coordination capabilities are critical for long term health of the system. In order for the tool to remain relevant and useful throughout the entire lifetime of the analyst's work and apply to the various ranges of experiences of different analysts, a training tool will have to address the needs of both an experienced analyst and a beginner. Mental models reflect individual goals and experience, so different operators see a system differently as well (See [9, p.111]). The System Dynamics model hints at characteristics which allow for easier tool adoption. Tools that will allow analysts to work more efficiently will be perceived to have immediate value and are adopted more quickly. Tools that have long term benefits of preventing errors but add more verification work on to their already full work load will be less easily adopted. In addition, the System Dynamics model suggests that the training of the beginner analysts is important for long term development of the resource work capacity even if error reduction is not immediately impacted. It is however the most difficult to do because of the barriers to learning with the complexity, visibility, and organizational issues of the model.

4. Implementing Billing Improvements: Design & Development

The tool development process for addressing Billing Error by improving the mental model of analysts is described here. The requirements of the visual representation of the complex rate model will be discussed, as well as other characteristics for the modeling tool.

4.1 Literature: Visual Modeling Tool Characteristics

The visualization of a complex model has been a common issue with the use of databases (See [14]). United Energy's billing model is no exception which analysts interface with through a large amount of tables and thousands of interrelated parameters. How can one see the change impact on one parameter, and trace the interrelationships? What is the best way for a person to view it?

Graphical representations of complex models have used Relational Models (or normalization) as well as logical models such as conceptual data modeling such as Entity Relational Diagrams. Logical models such as Relational Models (or normalization) "view(s) the task of population identification as a process of generalizing object identity from examples of structural dependencies (bundling/categorizing attributes that appear to .. co-occur) (See [10])." Entity Relational Diagrams are easier for novices to understand because they "assume a higher order of processing, in which object instances possess a natural domain identity," however, because of that extra processing, there is more possibility for errors to be made in drawing the relationships between the entities (See [10]). Figure 10 depicts the Billing model in a Relational model with the relationships shown between tables and parameters (using Gephi software). Figure 11 shows the Entity Relational Diagram of a handful of tables (the relationship between the tables is from Billing Operations documentation and relies on analyst understanding of the table relationships).

Figure 10: Relational model between Billing Parameters and Tables

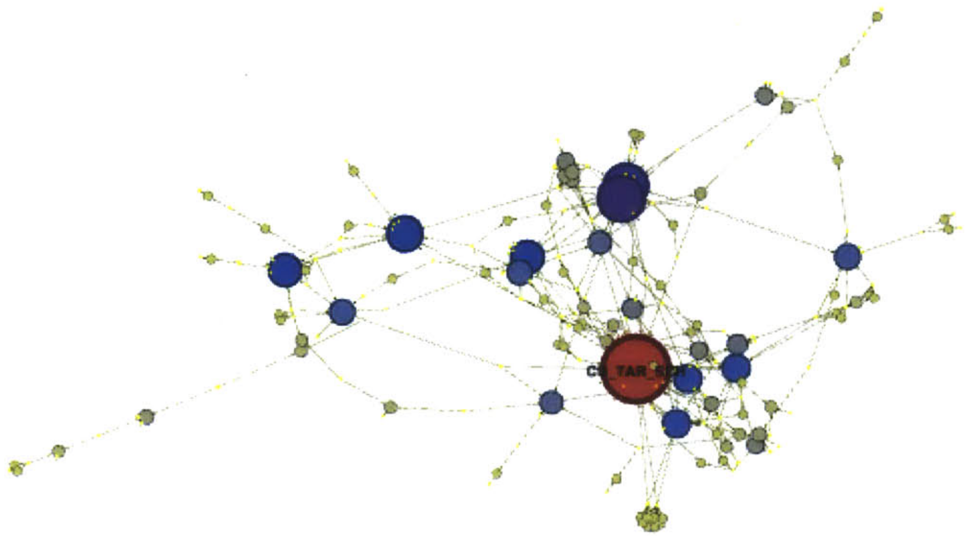
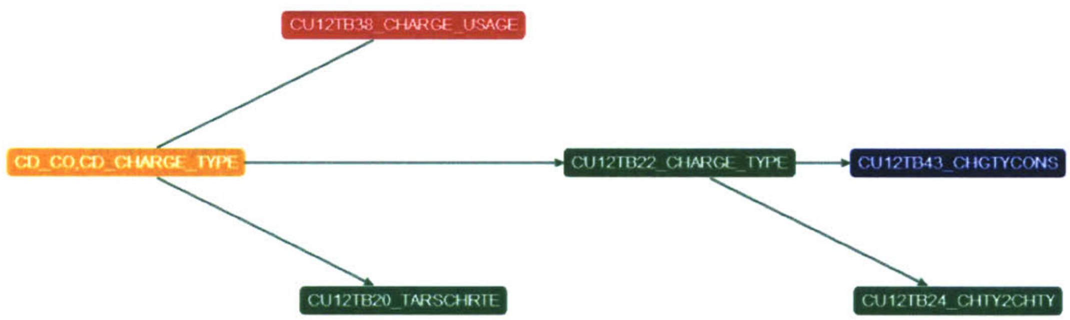


Figure 11: Entity Relational Diagram for a section of Billing Tables



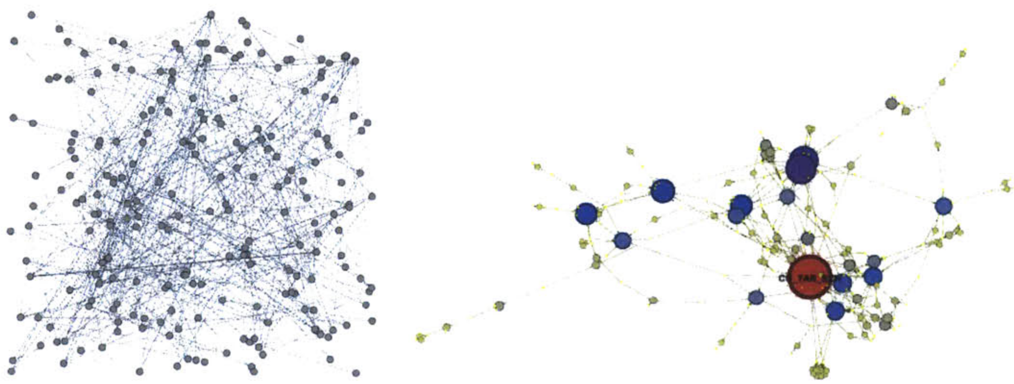
A trend toward Entity Relational Diagrams seems to be emerging. (See [11]) For our purposes of training new analysts to understand the Bill model, the Entity Relational Diagram is used as seen in Figure 11. However, as mentioned, the creation of Entity Relational Diagrams requires higher order processing. There is work on developing entity-relationship diagrams from relational models (See [10]), which is a promising approach for checking the analyst's concept of the table relationships in their entity-relationship diagrams.

4.2 Mapping Complexity

For humans to understand complex systems, "abstraction is one of our most powerful tools. Abstraction allows us to concentrate on the relevant aspects of a problem while ignoring the irrelevant." (See [9]) Thus, hierarchy, and grouping are used to "produce different degrees of detail appropriate to different users." (See [10, p.1]) Currently, we rely on the Billing analyst's expertise to plot the Entity Relational Diagrams, and their hierarchical groupings. The promising work of creating Entity Relational Diagrams from Relational diagrams may make possible a more systematic approach, where the relational diagram may have different levels of simplification to create a hierarchy that can be translated to entity relational diagrams. This may enable the generation of entity relational diagrams with multiple levels of hierarchy with accuracy. A technique for grouping within relational models is exhibited in Figure 12. When the Bill Model is mapped with parameters as inputs to the tables, it is much easier to see some relationships forming when groupings are made (such as groupings of degree or level of inputs). Certain parameters become apparent in centrality and weight, as critical parameters and have a high probability of being primary keys in the tables. This warrants further development of groupings to show different levels of hierarchy for the relational diagrams.

Thus the features discussed for improving the Billing analyst's mental model of the complex model are discussed. Firstly, a graphical representation is required, with correct and easy to understand relationships, here provided through Entity Relational Diagrams. Secondly, in order for the information to be more easily understood, the model needs levels of hierarchy and sub groupings. Additional features of the model tool for improving the analyst understanding of the bill model are described, because "there are right ways and wrong ways to show data; there are displays that reveal the truth and displays that do not. And, if the matter is an important one, then getting the displays of evidence right or wrong can possibly have momentous consequences." (See [15, p.45])

Figure 12: Relational model of Billing without & with Grouping



The Billing model is mapped using Gephi software with fields as inputs to table. Without grouping is (on left) and with grouping of weighted in degree is shown(on right).

4.3 Process Design – Determining Analyst Needs besides Visual Model

The creation of a tool to help analysts understand the model is actually the creation of a product which requires the full cycle of design and development. Ulrich and Eppinger describe the iterative process which involves cycles of prototyping, testing, and re-prototyping till the design works out all the issues to meet the specifications (See [12]). For the tool to be effective, it has to fulfill the analyst's needs. The process of determining analyst needs includes gathering raw data from analysts, which was pulled off of a survey and through interviews and the safety system analysis of the billing procedures, as well as through feedback during the prototyping phases.

The results from Surveys and Questions were not statistically significant since the sample size was so small, but the few (less than 10) results that were returned were in consensus of several issues:

(1) Tasks are not always clearly defined from the beginning of the process

(2) Process guides are not always followed

(3) Finding documentation is difficult, non-standardized documents, and the procedures, manual, and even verification are manual processes.

This suggests that the system level constraints from the Safety Systems analysis are not being met on a consistent basis. A Procedural Checklist integrated into the tool, should have those characteristics listed and described by Leveson in her treatise on safety system below (See [9]).

System-level constraints Recommendations:

- Clearly Defined Responsibilities for Analysts, Regulations, and ITT
- Establish Standards and requirements
- Correct, complete, up to date information
- Visibility of tasks and effects

Previous Tool characteristics for aiding in Bill modeling are also studied in Figure 13.
The pros and cons give an idea of what characteristics an effective and enduring tool should have. It should be noted that although the Tariff Explorer tool was useful for a short duration in training of analysts, it was eventually abandoned when the analysts' expertise surpassed the need for it, and the tool updates were stopped.

Figure 13: Tool Comparisons

Old Tools	Pros	Cons
Tariff Explorer	• Microsoft access capabilities • Simplified Bill Model • Important tables and copy books	• Not visual • No references • Not easy to update • Did not grow with analysts
CSS Data Dictionary	• Used on a daily basis, good functions • Definitions/decodes • Relationship between tables and fields	• Only one level of hierarchy for relationship between tables and fields • Hard to see how all the pieces fit • Not easy to update (assign new values to each field)
New Tool	• Same as above plus… • Visual Map (multiple levels of hierarchy) • Documentation references • Procedural references • Easy to update/maintain	• **Works in Chrome, not IE8** • **Took time to create since needed to learn javascripts and html off of examples**

Visual Description

Tufte has written about how to visually display causality in sometimes complicated relationships. (See [15]) In his interface for guiding museum visitors to exhibits and facilities, Tufte displays what characteristics are required for an interactive self-teaching visual guide. Similar to Tufte's museum guide, a billing analyst needs to navigate their way through the bill model, with relevant and accurate information being shown with as little clutter as possible. "Right from the start, this opening panel shows the scope of information made available. Only a small part of the screen is devoted to computer administration." (See [15, p.146]) In what Tufte describes an "architecture of content", the information becomes the interface. As Tufte explains, visual displays should place data in an appropriate context for assessing cause and effect, which requires accurate information and picking what information is relevant.

Billing Analyst Needs for Visualizations:

(1) Hierarchical Interactive map of Bill Model so analysts can teach themselves, can see general, or dive in deep

(2) Combines both Documentation Reference and Database information at each layer

(3) Shows critical areas of Billing that should be considered for Tariff Modeling

(4) Procedural references for Tariff Modeling

(5) Updateable, easy to maintain, and grow with the group

After determining analyst needs, an important part of the design process is establishing relative importance of the needs. This is often necessary because of there are often trade-offs in order to "allocate resources in designing the product. A sense of the relative importance of the various needs is essential to making these trade-offs correctly (See [12])." In order help decide whether features are critical, and which are not as necessary, we prioritize the billing analyst needs. The analysts can be categorized into two types: experienced analysts and inexperienced. The value provided by characteristics can help the analyst in two ways as described by the System Dynamics model: helping them work more efficiently, and/or helping them to work more carefully. Some of the characteristics affect how efficiently work is done and their values as described in Figure 14 below:

Figure 14: Tool Features and Value to Analysts

Characteristics	Positive Effects	Time effects	Analyst Type	Error effects
Visual Hierarchy	Mental model Error proofing?	Neutral	New trainee	Help (latent need)
Documentation	Mental model	Helps	New trainee	Help
Database interaction	Mental model	Neutral	New trainee/expert	Help
Procedural references	Error proofing	More steps	New trainee/expert	Critical

It is difficult to prioritize the characteristics. In order to help all analysts of a wide range of experiences, ideally we would like to be able to provide all the characteristics. With software rather than a physical product, there is more flexibility in being able to provide many characteristics, but given a time constraint in developing the tool, it would have been better to concentrate on a few key characteristics. The characteristics to aid in the adoption of the tool would be those that provide value in helping them work more efficiently. Unfortunately, most characteristics do not help in immediate work efficiency except for the fact that the tool traits may be provided all in one easily accessed place. The less experienced analysts who need to be trained to become experts, asked for documentation that is difficult to find and organize. In terms of error effects, all the characteristics should help with preventing errors, but having a procedural reference is critical for providing a standard checklist for both experts and new trainees. Unfortunately this requires more steps and adds more work.

Software tools have an interesting characteristic that they can provide different functions to different customers all at once in one place. On the other hand we run the risk of trying to develop all characteristics with poor quality. It may be possible to provide all functions with software, but it still requires time to develop, which limited this project. We therefore should choose features for the faster adoption and integration into the work place together with the most critical features to be the most effective in the long run. Thus in hindsight, it may have been better to concentrate on characteristics for higher work efficiency plus error reduction and implement the procedural check list at the same time.

4.4 Bill Model Tool Characteristics

A Screen snap shot of the Bill Model tool is shown in Figure 15. The bill model tool characteristics are listed below:

(1) Free Web based code with United Energy created server
→can support many simultaneous users
(2) HTML Web based code which uses Arbor.js a MIT javascript visualization library for rendering visual models using jquery and web workers
→ creates nice looking maps that are relatively easy to modify
→uses clickable, hierarchical interactive functions with maps and documentation
(3) HTML Web based code can also use asp.net C on the back end to interact with the database for queries
→ Can interact directly with database so that information is updated as the database is updated

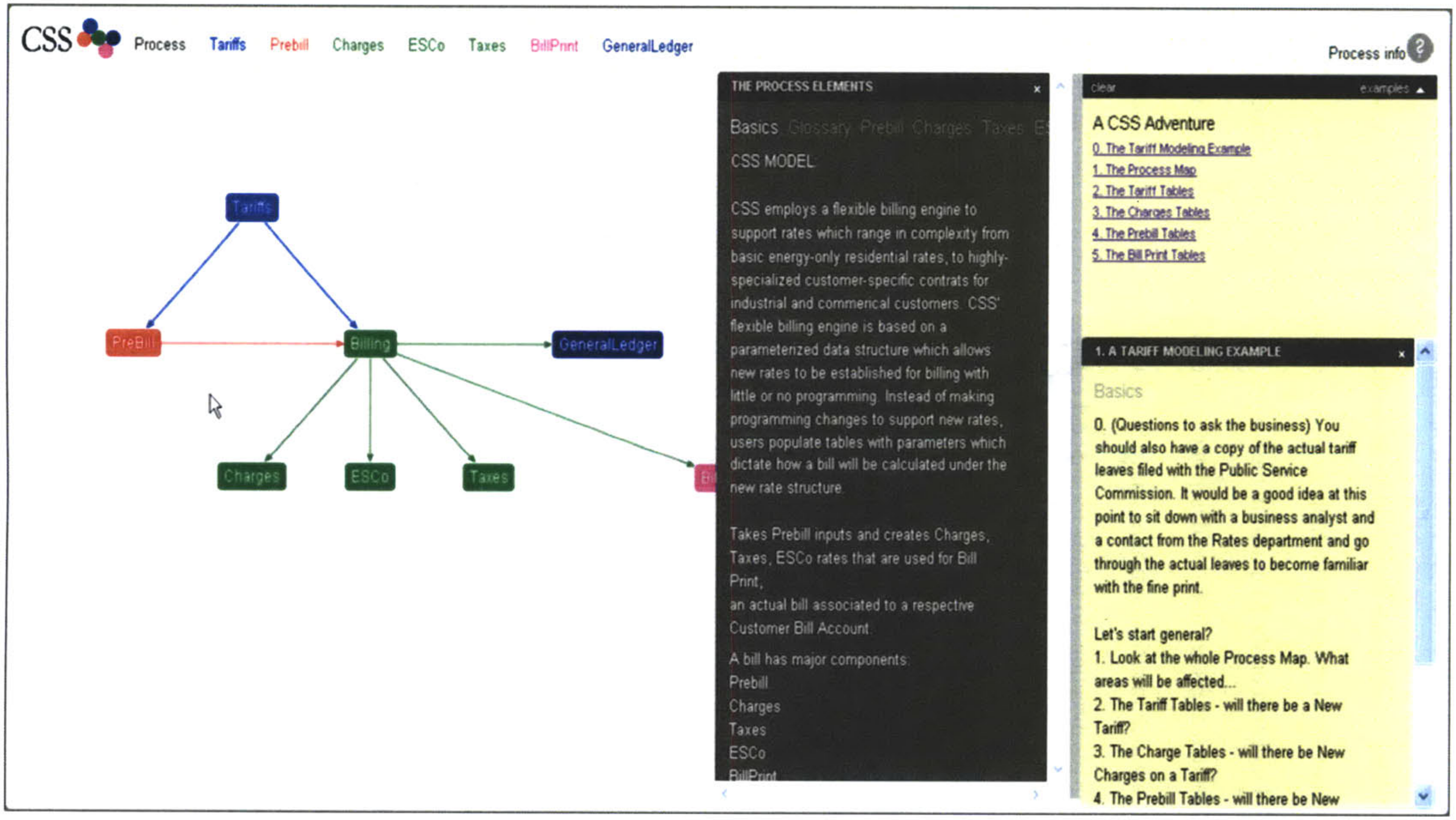


Figure 15: Screen Snapshot of Model Map Tool

Tool Description

The visual layout of the tool in Figure 15 includes clickable information that becomes the interface. Shown are the Billing Model areas displayed in the header, as well as Bill Guide Map, written descriptions of each of the elements in the Map, as well as directions to follow for a model change. Each Bill Model area on the Map and in the header is color coded, and clickable. The text for the Process Element areas are detailed descriptions of each area of billing drawn from a variety of references which the Billing analysts have found useful over the years. The Tariff Modeling Example gives directions to follow for a model change. When a specific model area is clicked, such as "Charges", then the central Bill Map area will display the tables critical to charges in an Entity Relational Format. The descriptive texts in the Element areas are replaced by individual descriptions for each chart. The Tariff Modeling directions are replaced by more specific directions for a charge-type modeling change. In addition for the Billing analysts to understand the specific tables and their interactions, each table is clickable which brings up information on the fields of each table. Function buttons appear for the query interface to the database for specific model parameter values, which is necessary for in depth understanding of the peculiarities of a model change.

Billing Error Example

The "YQ/YR" modeling change which we described early can be followed on the tool, with process steps to prevent the error. The addition of a new charge type would involve first looking at the top view of the model map in Figure 15, and identifying through the Bill model map the affected Charge type area. Once the Charges area is clicked, the process of following a Charge type change would be read. The critical tables shown in Figure 16 would thus be checked, and the formerly neglected sub table of CU12TB24_CHT2CHTY. By interactively clicking on the CU12TB24_CHT2CHTY table, the fields would be displayed. The incompletely analyzed parameter of TYPE_CHG could be checked for the charges "YQ/YR" are modeled after using the database queries as described in the process steps. Thus, the critical tables and procedures, together with the database interaction give an analyst a concrete process for understanding a bill model change and its effects, helping to prevent time consuming errors.

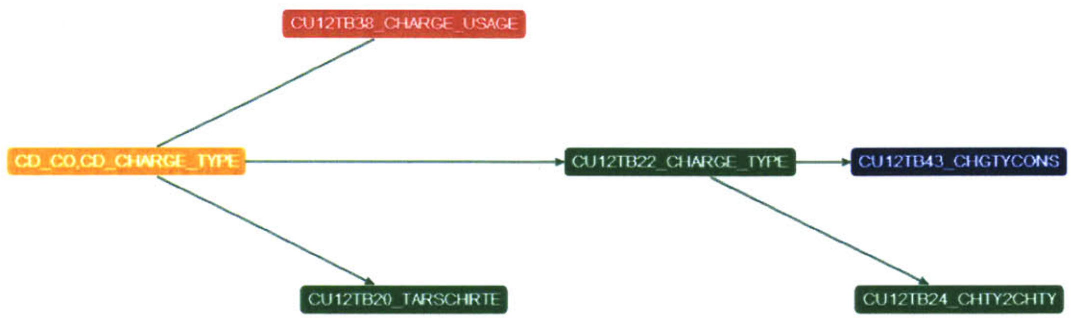


Figure 16: Charges Entity relational table with fields and queries

4.6 Billing Feedback Response to 1st change request

A working group of 5 experienced analysts was created for initial feedback on the tool and for eventual takeover in responsibility for maintenance and improvement. During the feedback stage, the working group who were familiar with the tool's features, had installed the tool, but a week after being exposed, had not updated the features or used it in everyday work. While explaining the additional features, several workers asked about adding certain tables that they were requiring for model changes in the futures, which indicates that the tool could be adopted and have beneficial effects on both work efficiency and work validation.

Requests were for added functionalities:

1) Number of Lines returned from Query to check changes
2) Additional options in Query Builder "where" functions
3) Added Tables

Requests were made for Fixes:

1) Bugs in display
2) Missing, incorrect table relationships
3) Incomplete documentation/ bill model map areas (how to add complexity)

Some analysts were making plans to try to use the tool during their next modeling changes, without any outside pressure to do so. The finding of mistakes in the relationships in the entity relational diagrams, suggest that a systematic approach for converting the entire bill model relationships between tables and parameters into simplified hierarchical levels of entity relationships is needed to make the tool comprehensively accurate. The updatability and maintenance of the tool is another area which needs to be assessed. Other than questions of accuracy and completeness, in interviews with the working group of analysts, the tool did display the characteristics that the analysts requested:

(1) Hierarchical Interactive maps of Bill Model so analysts can teach themselves, can see general, or dive in deep
(2) Combines both Documentation Reference and Database information at each layer
(3) Shows critical areas of Billing that should be considered for Tariff Modeling
(4) Procedural references for Tariff Modeling

4.5 Relevant Metrics for Suggested Improvement Assessment

As mentioned earlier, it is difficult to analyze the impact of a tool that seeks to prevent errors. How does one measure errors that never happen? Especially when the errors that do occur are relatively infrequent and have long stretches of time between occurrences? If one had enough time, one could analyze the error frequency over time, but in the time frame of this project, this has been impossible. We therefore use two indicators; feedback from the analysts from one on one interviews, and the analyst's most valuable commodity: time spent using the new tool.

Additional time spent on the tool is time not spent on other work. How much the billing group uses the tool is an indicator of the tool's success. The earlier System Dynamics analysis suggested earlier, that during early tool adoption, there is a great deal of inertia to overcome because familiarity with the tool is low and needed learning of the brand new tool is at the peak. Additionally, the value of the tool is yet unknown so busy analysts are less inclined to try a tool that might not help them be more productive, and uses up more time to learn and use. The likelihood of tool usage increases if an analyst perceives that the tool may help them work more efficiently, or answer questions that they want to verify. That is why during the development phase, any voluntary usage of the tool for aiding with actual work is indicative of its positive effects.

4.7 Further Improvement Focus Areas/ Road map

Ideally, in order to study whether the tool is in the process of successful adoption, the amount of time spent using the tool, and which function the analysts are using, should be documented over time. The measure of the new tool time used, as a metric for the efficacy of the improvement process, should be compared to the analyst feedback on the tool.

Improvements in billing process not addressed by the current tool would include: further standardized handoffs from Pricing and Regulation to Billing, more detailed standardized handoffs from Billing to Information Services, verification of their own model changes by Information Services (not just by Billing analysts), and finishing development and completion of the Verification tool for billing changes.

Improvements for this bill model tool development would include: further query functionality, and a completeness and accuracy check by systematic entity relational diagram generation from relational models compared to analyst expertise and documentation. With the generation of the full entity relational diagram, it may be possible to analyze the model itself for simplicity and robustness for future changes.

For the tool to become adopted, and be successful over the long term, it needs to be able to grow with the analyst group and change with the model. A working group for maintenance and improvement of the tool was created with the following responsibilities:

(1) Maintenance of Content

(2) Gather recommendations from other analysts

(3) New Functions - interaction with the Database through table specific queries

5 Conclusions and Recommendations:

5.1 Conclusions

Currently there are many methods for analyzing the possibility of errors that are practiced by organizations who are concerned with safety or error prevention. In situations where error occurrence is random and difficult to track, metrics of hazardous conditions can be found through System Dynamics modeling. Qualitative indicators that are easier to observe, but difficult to measure such as stress, may be linked to the dynamic behavior of quantitative indicators that may be tracked with time. In this work, we propose a method to find an appropriate metric for error analysis, by determining the direct quantitative triggers to or from the qualitative indicators of hazard conditions. A System Dynamics model is generated and used in concert with other system methodologies to give insight into triggers and policies for creating a lasting improvement process. The quantitative indicator behavior, in the case of billing errors at United Energy, was found to be the amount of time spent on verification work, which was used to suggest whether the system is moving toward health or hazard.

The System Dynamics model gave suggestions on a macro scale for improving billing operations. This included the levers of building up verification and coordination capabilities of the billing analysts (especially inexperienced analysts), increasing visibility of the model and processes, and increasing the work efficiency or lowering the work load. There are macro factors of hierarchy, communication structure, politics, and culture which may keep the "right" things from being done. Project management should encourage employees to keep standards that are clearly visible and often revisited. Ideally, there should be avenues of communication and feedback from all levels of hierarchy, and clear responsibilities assigned for chasing down issues and solving them. Additionally, best practices should be shared through easily accessed documentation and meetings, and tools. The model also gave us insight on how an improvement process might develop, and what characteristics to target for long term adoption and effectiveness.

We focused on the Billing Operations group for project improvements. The processes owned by the Billing Operations group were analyzed in a Safety Systems approach, where a matrix with possible errors for each process step was created. Through the Safety system analysis, gaps in the current Billing Operations processes were observed, and the following target objectives for the project were created in order to reduce errors:

(1) Create a model visualization tool for billing analysts to aid in model change interpretation
(2) Improve standardization of documentation and processes for handoffs

Frequent analyst feedback of prototype modeling tools led to the development of an internet based program with javascripts which is a hierarchical interactive map of the bill model. The tool has received positive feedback from the analysts which is being integrated into their workstations. Through a model visualization tool integrated with a model change checklist, the analyst can better understand which parameters in which tables and parameters may be impacted. A historical error "YQ-YR" was traced and found to be prevented using the procedural checklist developed. However since the tool functions as a model map and repository for model documentation and change methodology, it requires maintenance and ownership by the analysts themselves. As such, a working group of analysts has been organized to take responsibility for the tool maintenance and for further development of tool features. Future functions of the tool have been identified as important features for error reduction. This includes a query into the database for specific special case analysis, as well as automated verification of actual price values.

In order to create a policy that reduces billing, a systems approach is found to be effective in determining the high value drivers that should be targeted, as well as detailed characteristics for an improvement process. To conclusively prove the metric of time spent doing actual coordination and verifications is a driver for increasing understanding of the bill model and reducing change, more data on all these variables are needed by all the analysts as they interact with the tool over the long term. In conjunction with the analysts' qualitative views on the improvement process, the quantitative effects should be studied dynamically to determine the acceptance and quality of the tool.

5.2 Recommendations for other areas of research

As mentioned in the System Dynamics policy analysis, in order for the state to drive toward the greatest efficiency, the actual model itself should be tested for simplicity and robustness against changes and possibility of errors.

> "Simple tasks are being automated, and humans are increasingly responsible for the complex tasks and decision making not included in these models. An alternative is to build models that look beyond the task and environment and incorporate human cognitive processes." (See [9 p206])

All the interrelationships between the hundreds of model parameters, the model tables and their parameters should be mapped completely. This is true also just for the development of the visual map for the tool in order to create a comprehensive set of Entity Relational Diagrams. The complex model should be simplified in several layers of hierarchy, perhaps through relational model groupings, and translation into entity relational diagrams. This systematic approach should be checked for accuracy. In testing this model map, specific examples of historical changes and past errors should be analyzed.

The particular process improvement targeted for United Energy was the visualization of a complex model to display interrelationships between entities. Understanding the content of enormous databases such as customer accounts and their interrelationship such as through a billing model is a challenge for any company which provides individualized services to millions of customers. This is a common problem that any organization that deals with large complex data bases has when there are complex interrelationships which may help to define the identity of entities. The visual modeling of such interrelationships to simplify complex models and to display interrelationships is useful for many kinds of organizations such as Amazon, that deal with multitudes of customer accounts for service, billing, marketing, or even research purposes. Amazon has stated the mission of being "the most customer-centric company on earth", and is intensely interested in customer behavior and stores enormous amounts of data on customer information and activity. A database visualization tool with interactive Entity Relational Diagrams for billing customer accounts is useful to such a company as Amazon. The process of displaying interactions through relational models, and the creation of a simplified model with hierarchical levels to help create the visualization tool, may also be useful for determining patterns in customer behavior for marketing research.

The system methodologies including System Dynamics and Safety System Analysis are used to assess the billing operation system and process, for a project management plan for the development and implementation of a tool to reduce billing errors at United Energy. This process may be adopted by many organizations seeking to find metrics for hazard analyses, to prevent errors in non-standardized work processes. Companies which need to provide reliable customized services including utility companies such as United Energy, and health care companies such as Aflac Insurance, may find such process improvements useful for error or accident prevention.

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