

Chapter 4

The Framework Model

4.0 Introduction

This field research has been conducted at the facility of a firm's subsidiary, which will be called 'the firm'. As delineated in Section 3.7 (p.163), the firm provides a service of mixing powdered blends and packing. It specializes in a wide variety of consumer packs, such as health formulations, baby foods and baking products.

This type of food handled by the firm, dictates the high level of quality standards necessary to remain in business, but also compels the firm to maintain high effectiveness in order to remain profitable in the global economy where within this line of businesses, the competition is very intense and being profitable is tough.

Most jobs at the firm do not require high technical skills or a high level of education. The main skills required are diligence and accuracy. Due to the intense competition in this area, it is imperative to hire employees at minimum lawful wages. In a situation of decreasing sales, the current policy usually includes layoffs, and dismissals or temporary leaves.

The concurrent objectives of maintaining a high level of quality standards, while using minimum costs, have obviously created a host of problems for the firm's management.

Meeting the high level of quality standardization, as explained in Chapter Two, demands more than just diligence, it requires a deeper understanding of the job and keeping up a zero-defect production. Furthermore, quality culture demands certain special investments for the short and long term (Saad and Siha, 2000; Gore, 1999; Detert et al., 2000), which might cost considerably more in the short term. Conversely, preserving low costs in order to stay profitable affects exactly the necessary requirements for achieving a high quality culture level: confidence of the employees in the work place, sense of participation, motivation and the desire to learn and advance. The two conflicting objectives, i.e., reducing costs and facilitating a quality culture, compelled the firm's management to seek a better way of leading in order to attain both objectives simultaneously, rather than compromising one for the other. The requirement of keeping

the costs low, which causes temporary employment for some of the employees and low salaries for all of them, brings about a lot of pressure, which creates problems concerning the level of quality of the production processes and lately has a negative impact on profitability. The decline of the firm's profitability in the last two years has been very significant to the firm's management and for the firm's owner.

The application of the system dynamics approach to analyze and understand the problems of the firm requires the involvement of all concerned parties within a group model-building process. This research provides an opportunity for the firm to share divergent views on the issues facing this company. The following sections will introduce the methodology of the research, the process of building the model, the model and its behaviors, validity tests, sensitivity tests, the model results, and policy analysis.

4.1 Research Methodology

The research methodology of this endeavor is based on the system dynamics approach. The interaction between organizational effectiveness, quality culture and employee's health necessitates the use of many factors which I assume cannot be related by linear relationships.

The methodology of this research includes:

1. The process of choosing the participants for the group model-building process,
2. Deciding to use or not use a preliminary model,
3. Providing scripts for the group modeling sessions,
4. The process of building the conceptual model,
5. The process of building the formal model, and
6. Learning about the behavior of the system and about the relationship among the variables.

4.1.1 Accepting the Decision to Apply a Quantitative Approach Using System Dynamics

System dynamics models which are used for understanding the cause and effects of a problem and the behavior of the system as the result of this problem follow two approaches or some combination of these approaches. The first is a qualitative approach that focuses on system feedback mechanisms that demonstrate the relationships among interactive variables. The second is the quantitative approach where relationships among variables are quantified and the model is simulated.

Quantitative models are used if the goal of the modeling effort is to achieve a full understanding of the system's behavior. It is also preferable when the audience lacks the abilities required for analytical thinking (Wolstenholme, 1999). Given these two reasons, it was decided to use a quantitative model in this research. Nevertheless, for completeness purposes, the qualitative model was also formulated by the group.

4.1.2 The Process of Choosing the Participants for the Group Model-Building Projects

The process of choosing the participants for the group model process raised two issues: a) how many people to involve and b) how diverse should the group be. The decision that was accepted by the enterprise's CEO and myself was to include only workers with direct connection to production. This means workers were included on the team from production, maintenance, quality, inventory and operation departments. The CEO suggested workers that are valuable to the enterprise and are able to contribute to the building of the model. I interviewed all of the recommended workers. After the interviews, we chose the participants under the following conditions: have at least one participant from each of the departments and have the most diverse group possible. Some participants were at the managerial level and some were production workers. We agreed that all participants should be permanent employees.

The final group consisted of nine workers including the CEO, the operation manager, the maintenance manager, the inventory manager, a food engineer, the quality

manager, the quality assurance employee and two production employees. (See Appendix A)

4.1.3 Deciding to Use or Not Use a Preliminary Model

Using a preliminary model may speed up the model-building process, but might decrease the degree of ownership with respect to the model as experienced by the group (Vennix, 1996). In this case, it was decided not to use a preliminary model, since there was no apriority knowledge concerning what kind of information was needed and what was available. Also, it was obvious that the more effort expended on building the model, the more it created ownership feelings and therefore would lead to more commitment.

4.1.4 The Group Modeling Sessions

All the sessions took place in a conference room, relatively far from the production halls and the office rooms. All sessions were planned for four and half hours including a break of half an hour at the end of the two first hours of the session. The last half hour in every session was used to summarize the effort of the day and listen to suggestions, feelings or any thoughts the participants had in mind. Since model-building is also a process of learning where mental models of the participants are changed, it was important to include methods that allowed interactions and discussion in every session, in order to improve existing mental models and to clarify the problem. The sessions were planned ahead of time, with an intermission of three weeks between sessions. A certain day of the week was chosen by the participants as the preferable day for the sessions. The firm provided refreshments and food during the sessions. The participants tried not to use their cellular phone during sessions.

All sessions were recorded and included: the daily agenda (including what was expected from the group during the session including what outcomes were anticipated), summary of the previous session (including reports and results from the feedback questionnaire with respect to the previous session), and written materials which I prepared between the sessions. During the sessions, the participants also received homework or a list of challenges or topics to think about. In certain sessions, some

educational topics were discussed in order to develop group and individual consciousness for system thinking. A short description of each session follows.

4.1.4.1 The First Session

The first part of this session (See Appendix A) was dedicated to the introduction of all the participants and the introduction of the system dynamics approach. Furthermore, I provided the work place problems that I had investigated and discovered while conducting the interviews with them. I encouraged them to talk about these specific problems and moved to divergent elicitation - each participant was asked to express his/her opinion. After I had summarized all the issues that were revealed, we summarized them in order to find out if we all agreed on what had been discussed. Then, each participant had to articulate the problem as he/she understood it by writing it on paper. The papers were posted on the board and the group was encouraged to converge to one articulation of the problem.

At the end of the session, tasks for the second meeting were provided, while I explained these tasks and denoted the date and the mode of submitting the tasks. The tasks included the following answers to the following questions:

1. What are the main issues you would like for us to discuss in the group?
2. What are the important questions you would like to answer?
3. How can we build a better organization? What are the main ‘burning issues’?
4. How could a model of the organization be helpful and effective for all of us?

4.1.4.2 The Second Session

The main goal of the second session included an agreement on the problem statement. Other goals included defining the model boundaries, defining the time horizon for the problem, describe reference modes for the main variables and come up with an initial model (See Appendix B). The two last goals were not achieved.

I handed out several papers which included the following: summary and feedback of the first meeting, graph sheets, the articulation of the problem as defined by the group members (my version of what they wrote), a list of conduct codes and feedback forms which were supposed to be filled out in every session in order for us to improve the way the sessions were managed (See Appendix B).

I realized from the first session that participants used specific words that had different meaning for some of them. This impeded the effective communication among members of the group. Therefore, I prepared a guide for better communication (adapted from Miller and Miller (1997)). I introduced this topic, but the related exercises were postponed to the next session. (See Appendix B)

At the end of the session, I concluded with what was achieved, gathered the feedback forms and provided the task for next session, which was to think about ways to measure the chosen variables that we had agreed upon in that session.

4.1.4.3 The Third Session

The purpose of this session was to explore each subsystem in the organization with respect to the three issues:

1. The organizational structure and the way things are done;
2. The delays: material and informational;
3. The governing policies, the decision making system and the perceptions about the system and how they influence specific subsystems.

The desired outcome from the meeting was a deeper understanding of how things were done in the organization and the reasons why they were done in a specific fashion. The desired output was a list of variables for each subsystem and the relationship between them. (See Appendix C)

The session started with the goals that were not achieved during the previous session. We closed the first part of the session trying to understand what we have learned so far about the relationship between variables. I then handed out the summary of the second meeting and a list of guiding questions for exploring the subsystems in the organization (adapted from Forrester (1961)).

The session continued with communication exercises, based on handouts given to the participants in the previous session. I also handed out the participants' notes about the notion of "wants" (adapted from Miller and Miller (1997)). (See Appendix C)

4.1.4.4 The Fourth Session

The goals for this meeting were to continue exploring the dynamics of the enterprise, which we had not completed in the previous session. The desired outcome from the meeting was an agreement about the dynamics that exist among the subsystems

that included maintenance, inventory and logistics, and operation. The second desired outcome was to arrive at a better understanding of how things were done in the production and in the quality assurance subsystems. (See Appendix D)

In this session, I handed out the summary of the feedback obtained for the third meeting, the dynamic hypotheses and conceptual model for the inventory and logistic subsystem, the maintenance subsystem and operation subsystem. (See Appendix D) We ended the session summarizing what was achieved thus far and what needed to be accomplished in the following meeting.

4.1.4.5 The Fifth Session

The goals of this session included: understanding and working on the production subsystem, exploring the personal subsystem, revisiting the problem definition and if required, to modify it. Out of all the dynamic hypotheses of all the subsystems, the participants had to choose the most important dynamic hypotheses, which were supposed to underlie the full model. The group was expected to understand how structure influenced the behavior of a system.

The desired outcome of the meeting was an updated definition of the problem, with a list of the major variables that were responsible for creating the problem.

I handed out the fourth meeting feedback form summary and results, list of dynamic hypotheses of all the subsystems and the problem definition from the second meeting. (See Appendix E) I also gave out a list of questions about the personal subsystem, which included the facilitating questions about the personal subsystem, given to the employees of the group (not the managers). It was supposed to help them to explore the relationships in the personal subsystem.

The list of the dynamic hypotheses for all subsystems was handed out to three groups. They ranked each of the hypotheses on a scale from 5 to 1 according to two criteria:

1. How much do you agree with the hypothesis (5-very much, 1- no agreement)
2. How much is this hypothesis important in reference to the enterprise's dynamics and problem definition (5 – very important, 1 – not important at all).

This was a preparatory activity for building the full conceptual model. (See Appendix E)

4.1.4.6 The Sixth Session

The session's goals included: discussing the entire model of the organization in order to approve or modify it, choosing the main variables of the model, (whose behaviors were considered important for the study of the enterprise's behavior) and understanding how structure influenced the behavior of a system (which was an unfinished task from the fifth meeting). Finally, a discussion of measurement issues and the formulation of reference modes for the main variables were not done (See Appendix F).

The desired outcomes of the meeting included a list of variables, which the group had agreed on, and the way to measure as well as a reference mode for each variable. These last two activities were not achieved in this session.

I handed out the fifth meeting feedback form summary and the results, a list of the dynamic hypotheses for the entire system and a causal loop diagram for the entire system (See Appendix F).

4.1.4.7 The Seventh Session

The session goals discussing measurement issues, a goal from the previous session that were not achieved, drafting reference modes for the main variables (which was also not achieved in the previous session but also not in this session), examining and correcting the stock and flow diagram representation if necessary (See Appendix G).

The desired outcomes of the meeting were: a list of variables that the group agreed on and how to measure each of them (was not achieved), reference modes for each of them (was not achieved) and a corrected and accepted stock and flow diagram.

I handed out the feedback form summary of the sixth session with the results and a copy of the stock and flow diagram. Most of the work in this session was done in small groups (2-3 participants) while reaching consensus about the tasks later with the whole group.

4.1.4.8 The Eighth and Ninth Sessions

The main target of these sessions was to finish the tasks from the seventh session: graphing reference modes for the main variables and concluding how far we had gone and what was expected in the following session (See Appendix H and Appendix I).

The desired outcomes of this meeting were the two former goals that were not been achieved in the seventh sessions: ways to measure the list of variables that the group agreed upon (See Appendix H and I) and reference modes for each of them (was not achieved).

4.1.5 The Process of Building the Conceptual Model

The first phase of building the conceptual model was articulating the problem of the organization as it was perceived by the participants. This phase started with a divergent elicitation and continued with a convergent elicitation. Furthermore, the participants had to articulate the problem as they perceived it by answering certain questions. Using the answers of all the participants, I formulated the problem in two parts: at the organizational level and at the personal level. (See Appendix B) The problem articulation was introduced to the participants. They were encouraged to react and suggest changes to the articulation, until they reached a consensus.

The second phase included: defining the system boundaries, defining the time horizon for the problem, describing the reference modes for the main variables, and building the first initial conceptual model, which described the relationships between subsystems. (See Appendix C) Each of the reference modes were graphed by three groups separately. Each group had to explain their graphic description through their verbal description. The differences between the reference modes were discussed, until a consensus was reached.

The third phase dealt with building conceptual models for each of the selected subsystems. (See Appendix D and Appendix E) In order to build the full model, the group members were given all the dynamic hypotheses of the subsystems and they had to decide about the level of importance of each hypothesis in relation to the full model. After the less-important dynamic hypotheses were deleted, the entire conceptual model was developed by me and introduced to the group for evaluation and suggestions for changes. (See Appendix F)

4.1.6 The Process of Building the Formal Model

In order to develop a useful formal model, modelers must elicit knowledge from system experts - those who participate in the process directly in operational or managerial roles (Ford and Sterman, 1998). Knowledge elicitation for the formal model includes: the estimation of the parameters, the initial conditions and the behavior relationships that must be specified precisely (Ford and Sterman, 1998).

Formulating and simulating a model requires among others the gathering of data, eliciting knowledge and ‘playing’ with the model until a full understanding of the system’s behavior is achieved. Using a formal model presents many advantages: more information can be contained in a formal model than in a conceptual model, assumptions can be altered easily for different experiments, experiments can be performed with different structures, uncertainties and errors can be incorporated into the model explicitly, graphical output can be created easily and help the decision makers in understanding the real world’s behavior and once the model has been validated, it can be used reliably to simulate alternative model experiments without manual errors (Maani and Cavana, 2000).

Building the formal model requires the performance of certain steps: defining variable types and constructing stock and flow diagrams (See Appendix G), collecting detailed information and data (See Appendix H and Appendix I), formulating equations, simulating the model, validating the model, testing the model sensitivity and making changes until the model satisfies the people who are interested in it. All of these steps are repeated when the behavior of the model is unsatisfactory.

The process of building the formal model in this research started with the participants as a group and continued with the participants and other workers and managers individually. After the full stock and flow diagram was constructed according to the group’s selection of the main variables of the model, whose behaviors were considered important for studying about the real world behavior, the sessions ended and I proceed with the construction of the model following the above steps with the group participants (both individually and with other workers and managers). This process included breaking the full model into its subsystems, defining variables and stock and flow for each subsystem separately, gathering the data, formulating the equations,

simulating the subsystem, discussing the subsystem behavior with the related workers or managers, making changes until the subsystem's behavior was acceptable.

The next step was to combine the subsystems into a full model, to add linkages and loops that represent key relationships between subsystems or were relevant to the full model, changing equations as a result of these changes, simulating the model and making modifications until the model behaved satisfactory to the workers and managers.

The last phase in this process was to uncover flaws and improve the model. It included validating the model and performing sensitivity analysis. These steps led to more changes and modifications in order to obtain a robust model, which can be used with more confidence.

4.1.7 Conclusions Concerning the Group Modeling Process

As explained in Section 3.6 (p. 154), all the above stages and tasks were mainly based on three working techniques: first using the group participants' interaction so as to elicit tacit knowledge, use the system dynamic tools such as loops to create the conceptual model and converting the conceptual model through the use of mathematical formulations to a computer simulation model.

4.2 General Description of the Model

Building a system dynamics model is an iterative process involving many changes. The challenge is to be specific as much as possible while describing this iterative process without causing too much distraction and confusion. Therefore I decided first to introduce the accepted subsystems and full conceptual models in this section. Some of the important changes and modifications are introduced in Appendix J.

4.2.1 The Problem Definition

The group members provided the problem definition at two levels: The organizational level and the personal level.

4.2.1.1 The Problem Definition for the Organizational Level

The problem definition at the organizational level asserts that the organization does not have a clear strategy and therefore the people working at the enterprise do not know who the customer is and what kind of service they want to offer (for example, timeliness of delivery, level of quality, etc.). Today, the organization has different customers, and the workers have no understanding about who is important and how to discriminate between the different types of customers. Therefore their managers are not capable of providing them with clear guidance with respect to work patterns: they have difficulties in developing work methods that will support organizational policies (since there are no policies or the policy is unclear). As a result, management provides short-term solutions to problems that arise over time.

When information for the workers is unclear, strain at work increases and personal stress grows simultaneously. Stress causes more faults and more errors to occur, which causes more stress and more wasted time and resources. The more workers spend time with what is “urgent”, less time and resources are invested in what is “important”. Therefore less time is devoted to the development of work methods and quality improvement. This is a vicious cycle that reinforces itself.

4.2.1.2 The Problem Definition for Personal Level

The problem definition at the personal level as conceived by the group members states that for an external customer to be satisfied (for example, quality of product, quality of service), the internal customer (from the manager to the last worker) who provides the service has to be satisfied. Only a satisfied worker will be committed to his/her work and be motivated to invest in quality and contribute to the whole quality improvement process. Management can force quality procedures only to a certain level. Quality at last, depends on the level of the worker’s commitment, as long as the company provides the tools and time necessary to do the required job.

Motivation grows as long as satisfaction grows. Satisfaction increases/decreases as a result of several factors: level of interest in the work, management involvement, its relationship with workers, work conditions (personal and environmental), level of personal responsibility, level of participation, level of possible advancement or self actualization. Motivation will increase as long as the workers perceive the improvement plan as a very valuable program which can bring about very good changes. This is also

contingent upon management's support of the plan which can be expressed in terms of providing adequate training and the appropriate allocation of resources. It seems also that motivation will increase when job security is guaranteed.

4.2.2 Reference Modes

As explained in Chapter 3, reference modes encourage group members to view a problem in terms of a graph that depicts the patterns of behavior of a variable over time. These graphs help to view the long-term dynamic consequences of certain actions or policies. In this case, group members were asked to choose several of the most important variables that are significant so as to discuss their behavior over time. The three variables that were chosen are: time devoted to improvement, number of defects and profitability. The followings graphs depict these reference modes (See Appendix C).

4.2.2.1 Time Devoted to Improvement

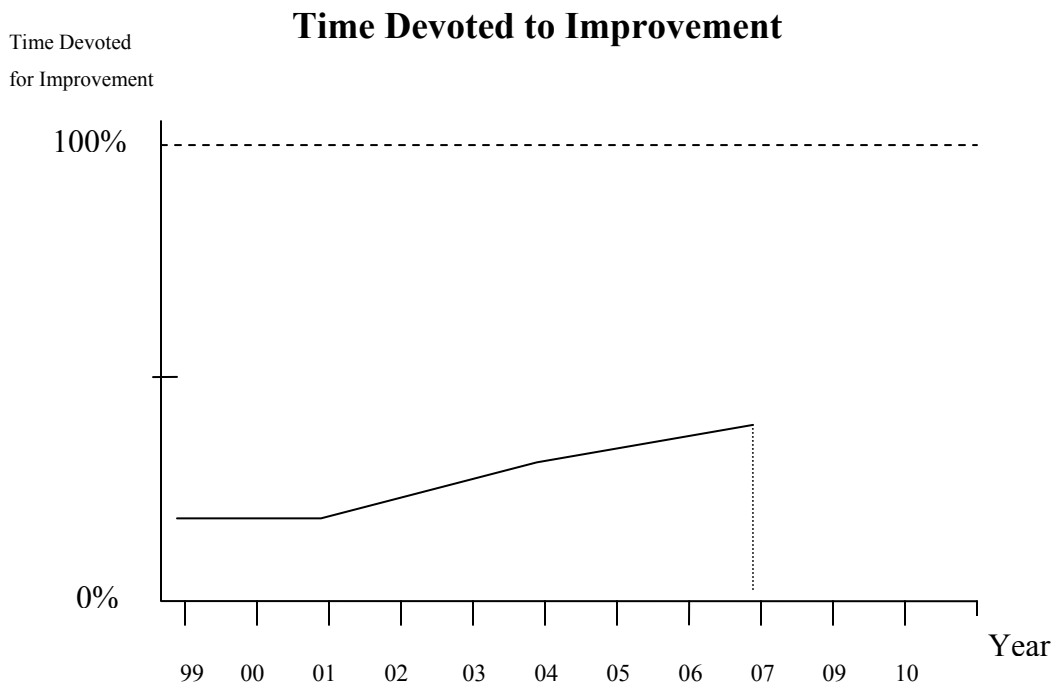


Figure 4-1: Reference Mode for Time Devoted to Improvement

The group members accepted that until several years ago, time devoted to improvement was very low and did not change considerably during these years. For each of the last two to three years, more time is devoted to improvement. The group believes

that this increase will continue in the future but at a lower rate (the slope starting at year 2004). In general, they implied that not enough time is allocated to improvement.

4.2.2.2 Percentage of Defects (Quality Level)

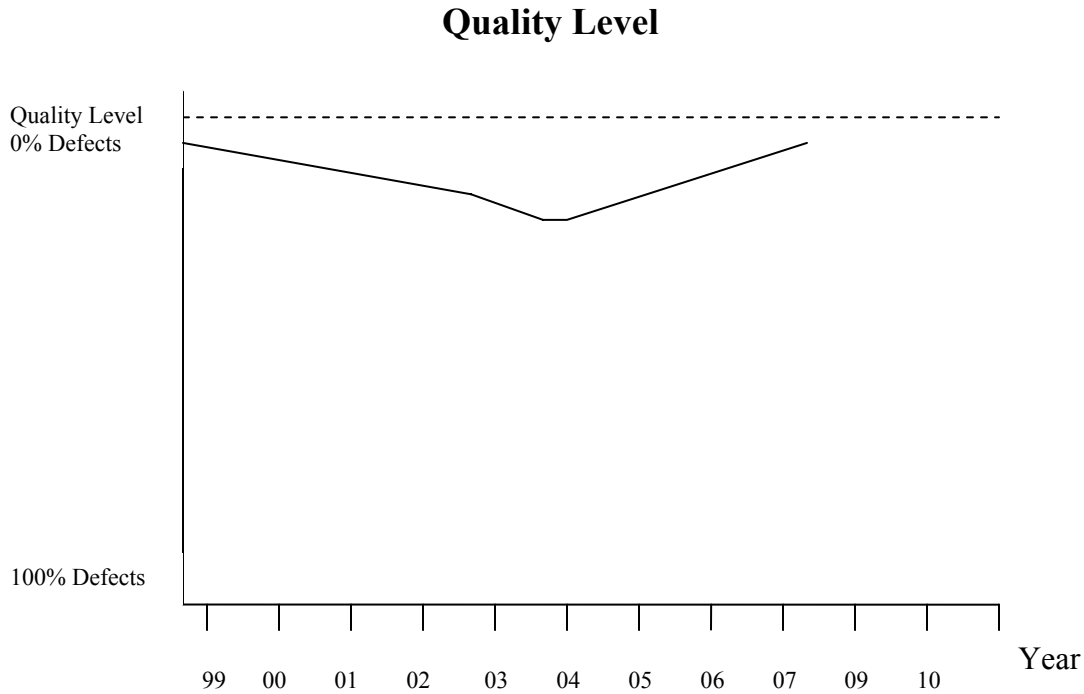


Figure 4-2: Reference mode for Quality Level

According to the group, the quality level was high several years ago, and decreased slowly during the last couple of years. During the last two years the decrease was even steeper, and now they believe that quality level is going to increase. They believe that quality level will approach 100% quality - meaning, zero defects in future years.

4.2.2.3 Profitability

The workers that were participating in the group model building process were certain that the enterprise is going to be more profitable in the future. At the present, because of the enterprise's acquisition of another organization, profitability was assumed to be constant in 2003/2004.

Profitability

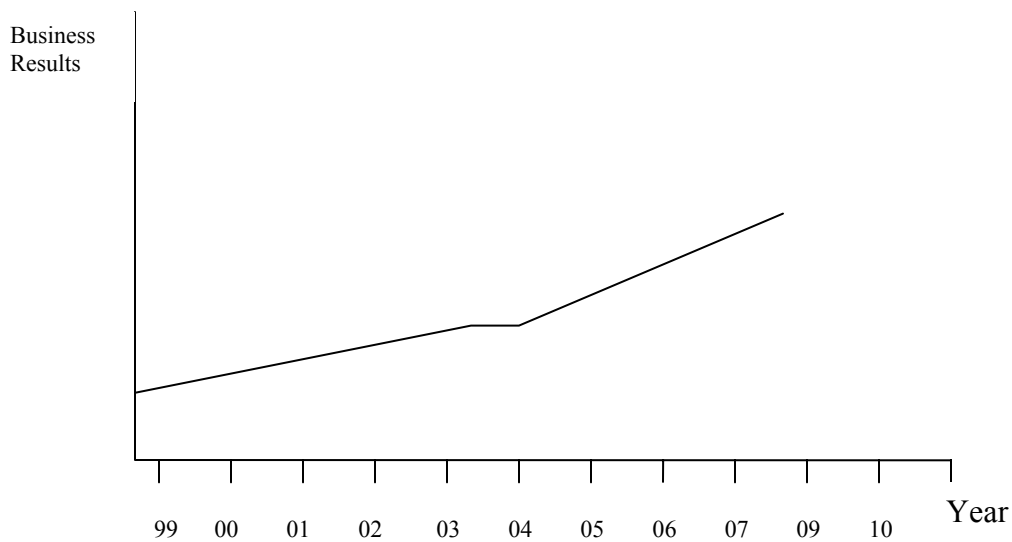


Figure 4-3: Reference Mode for Profitability

4.2.3 The Time Horizon

The group chose three years as the time horizon, which will be the length of time over which a simulation will eventually be run.

4.2.4 System Conceptualization

In this section, two conceptual models were built and introduced by the group members: The causal loop diagram linking all the variables they chose to be included in the total system model as a function of their organizational problem definition and a conceptual model that connects the subsystems of the whole model.

4.2.4.1 Conceptual Model for the Problem Definition Variables

Improvement Reinforcing Loop: When management methods cause employee satisfaction to increase, and management provides support for the improvement of program value, and also workers have job security, motivation tends to increase. Consequently, the commitment for improvement increases and so does the employees' effort devoted for improvement. Therefore, improvement results increase, which decreases the amount of defects and mistakes. This lowers personal stress, which increases workers' satisfaction and motivation even more.

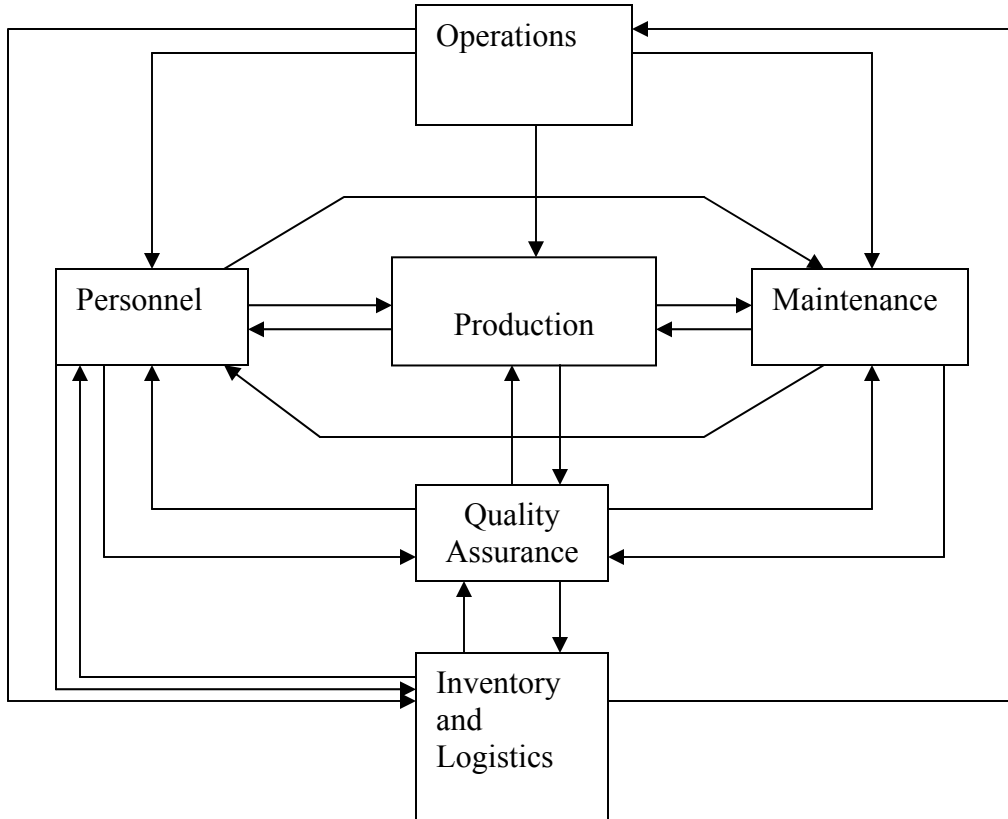


Figure 4-5: The Subsystems and their Interrelationships

- The production subsystem influences the personal, maintenance, and quality assurance subsystems and is influenced in return by operations, personnel, maintenance and quality assurance subsystems.
- The quality assurance subsystem influences the production, maintenance, inventory and logistics and personal subsystems and is influenced in return by all of the subsystems.
- The inventory and logistics subsystem influences mainly the operation and the quality assurance subsystem and is influenced by the operation and quality and the personal subsystems.
- The maintenance subsystem influences the production, the quality assurance and the personal subsystems and is influenced by them in return and by the operations subsystem.
- The personal subsystem influences all the subsystems that deal directly with production, i.e., the production, maintenance, quality assurance and inventory

and logistics subsystems and is influenced in return by all of them, including the operations subsystem.

4.2.5 Model Purpose

Section 4.0 describes the firm's recent situation. In short, the firm faces difficulties concerning the high level of quality standardization that is required for its products, while keeping wages as low as possible, and at the same time is concerned about the employees who are constantly under stress since they fear being laid off or dismissed.

In order to understand how work is managed and performed, one needs to understand the relationship among production, maintenance, inventory, quality and operations, and how they concurrently impact employees' stress and health. By understanding these relationships, work management and performance can be improved. The underlying premise is that changes will positively impact the health of the workers.

4.2.6 System Boundaries

According to the system/subsystem representation of Figure 4-5, all the variables that are included in the subsystems are considered endogenous, while the variables concerning subsystems like; marketing, administration, management, etc., are considered exogenous variables. Employees' health is impacted by the production, the quality, the maintenance, the operations and the inventory subsystems. This system boundary will enable the group participants to answer the three questions provided by Richardson and Pugh (1981) and are introduced in Section 3.3.2.2 (p.125): What are the physical processes in the system that are relevant to the problem, what are the perceptions of those processes and how are they formed and how do those perceptions combine to create pressures influencing the physical processes?

4.2.7 Subsystems and Full Model Causal Loop Diagrams

Each causal loop representation was built by the group during the group modeling process. (See Appendix D and Appendix E) As explained in Chapter 3, each subsystem is based on underlying dynamic hypotheses that depict the interrelationships of critical

variables over time that generate the problem behavior. These dynamic hypotheses are then translated into feedback loop diagrams, which are referred to as causal loop diagrams (CLD).

As it is anticipated, dynamic hypotheses are subject to changes during the group model building process. As I mentioned before, I decided to introduce the final accepted causal loop representations in this section. Some of the important changes and modifications are provided in Appendix J.

In order to build the causal loop representations the group participants were asked to rank each dynamic hypothesis according to its importance. The least important dynamic hypotheses were not considered further. (See the list of dynamic hypotheses and the ranking questions in Appendix E)

4.2.7.1 The Operation and Production CLD

At the beginning, the group chose the operations and production subsystems as two separate subsystems (See Appendix D and Appendix E), but, during the group modeling process, the two subsystems were merged into one subsystem as is described subsequently:

4.2.7.1.1 Dynamic Hypotheses for the Operation and Production Subsystem

When the production performance gap (The gap is the difference between the production performance target and the actual production performance.) increases, pressure on employees increases, decreasing the time per task, decreasing also the standard level of work, which increases work completion rate, decreasing production performance gap (loop B1). When production performance gap increases, pressure on employees increases, increasing overtime and decreasing the production performance gap (loop B2). When production performance gap increases, it causes the time devoted to urgent actions to increase, which decreases production performance gap (loop B3).

When production performance gap increases, pressure on employees increases, decreasing time per task, decreasing also the standard level of work. This causes more problems and faults to increase, which increases the level of interruptions in production, causing production performance gap to increase even more (loop R1). When production performance gap increases, pressure on employees increases, decreasing time per task, decreasing also the standard level of work. This causes more problems and faults to

happen, which decreases organizational productivity, decreasing also the work completion rate, thus increasing production performance gap even more (loop R2).

Operation and Production Subsystem

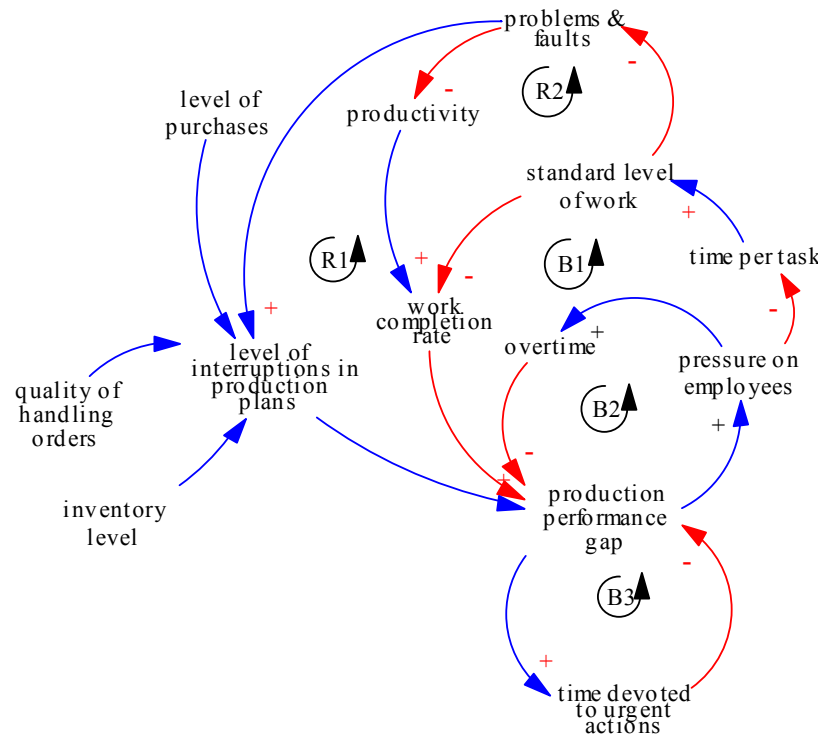


Figure 4-6: The Operation and Production Subsystem CLD

4.2.7.2 The Maintenance CLD

The initial maintenance subsystem causal loop model is represented subsequently. As explained before, the group participants were asked to rank each dynamic hypothesis according to its importance for the entire company. The least important dynamic hypotheses, which were chosen by the majority of the group, were not considered further. According to the group participants, the most useful and important loops are: B4, B5, B6 and R3. The condensed causal loop model using loops B4, B5, B6 and R3 is provided in Appendix J. It is used later in the full model

4.2.7.2.1 Dynamic Hypotheses for the Maintenance Subsystem

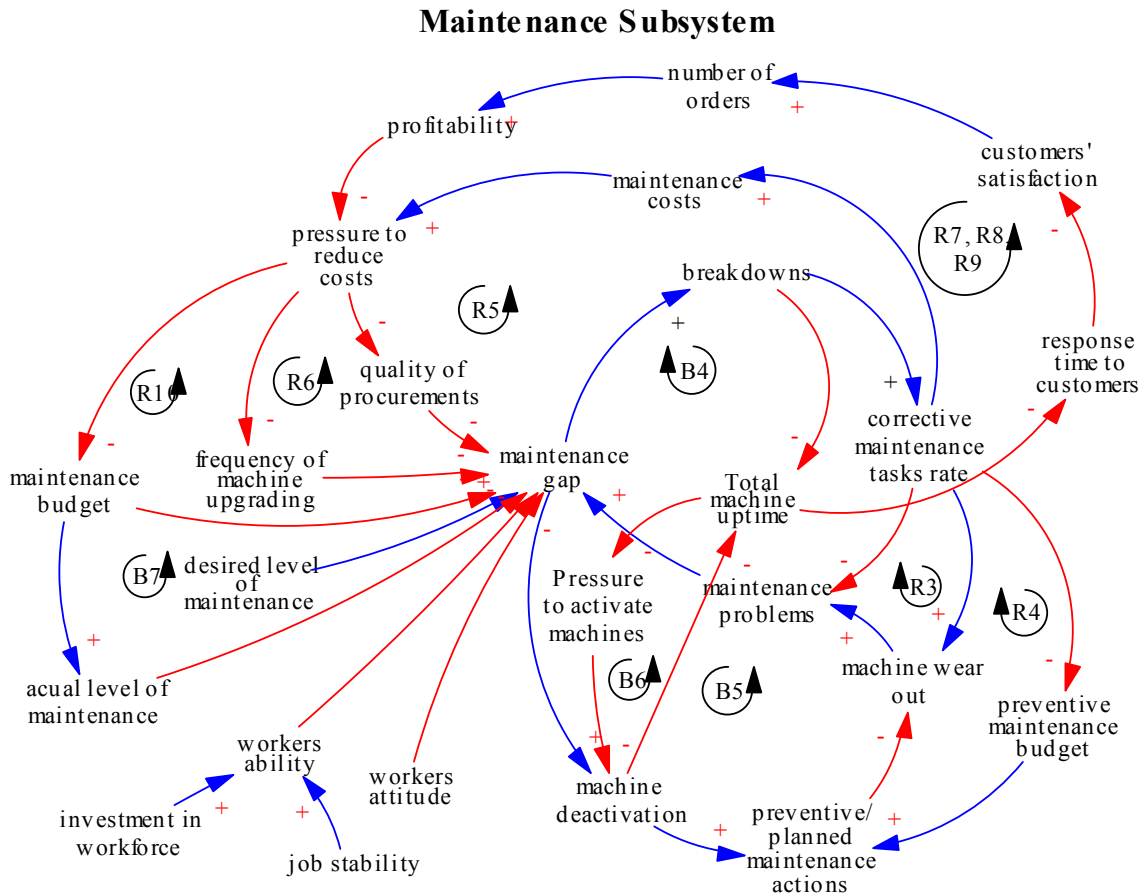


Figure 4-7: The Maintenance Subsystem CLD

As the maintenance gap (the gap between the desired preventive maintenance and the actual preventive maintenance) increases, the breakdowns rate increases, which causes the corrective maintenance tasks rate to increase (the urgent maintenance tasks), which lowers maintenance problems and decreases the maintenance gap (loop B4). As the maintenance gap increases, the machine deactivation rate increases, forcing more preventive actions. The more preventive or planned maintenance actions, the less machine wear out, less maintenance problems occur and the maintenance gap decreases (loop B5). When the breakdown rate is high, the total machine uptime decreases, which creates more pressure to activate the machines, which lowers the machine deactivation rate, and the total machine uptime increases (loop B6). When the maintenance gap is high, there are more frequent breakdowns, the corrective maintenance task increases, and maintenance costs rise. When maintenance costs rise, there is more pressure to reduce

costs. As a result, maintenance budget decreases and the actual level of maintenance decreases, which increases the maintenance gap (loop B7).

When corrective maintenance tasks increases, the machine wears out faster (less time is dedicated for preventive maintenance). When the machines wear increases, there are more maintenance problems. When maintenance problems increase the maintenance gap increases, and the breakdown rate also increases, causing more corrective maintenance tasks to be needed (loop R3). When more corrective maintenance tasks are provided, preventive maintenance budget decreases, which lowers the amount of preventive/planned actions. This causes for more machines to wear out and for more maintenance problems to occur. When the amount of maintenance problems increases, it increases the maintenance gap, and also the breakdown rate increases, causing corrective maintenance tasks to increase (loop R4). When the maintenance gap is high, there are more frequent breakdowns, more corrective maintenance tasks have to be taken, and maintenance costs rise. When maintenance costs rise, there is pressure to reduce costs, the quality of procurements decreases (R5), the frequency of machine upgrade decreases (R6), and the maintenance budget is lower (R10), causing the maintenance gap to increase even more. As the maintenance gap increases, the machine breakdowns rate increases, causing the total machine uptime to decrease and the response time to customers to increase. This lowers customers' satisfaction, the number of orders and organizational profitability. This in turns increases the pressure to reduce costs, which will negatively affect (reducing) the quality of procurement (R7), the frequency of machine upgrades (R8), the maintenance budget (R9), all of which will increase the maintenance gap even more.

4.2.7.3 The Quality Assurance CLD

The initial quality assurance subsystem causal loop diagram is presented subsequently. According to the group participants, the most useful and important loops are: B7, B8 and B9. The condensed quality assurance causal loop diagram is provided in Appendix J. It is used later in the full model

4.2.7.3.1 Dynamic Hypotheses for the Quality Assurance Subsystem

When the gap in the current (daily) scheduled tasks (the gap between the number of completed scheduled tasks and the delayed ones) increases, the time devoted to urgent

tasks increases, lowering the current schedule gap (loop B7). When the gap in current schedule increases, the gap in prevention and training schedule (the gap between what is done for prevention and training and what should have be done) gets bigger. This causes more problems and faults to occur, and causes more stress to the workers, subsequently increasing the time devoted to urgent actions (the urgent tasks are part of the daily schedule) and lowering the current schedule gap (loop B8). When the gap in prevention and training schedule gets bigger, time devoted to build quality culture decreases, causing more problems and faults to happen, and increasing stress to workers. This in turn increases the time devoted to urgent actions to increase and lowering the current schedule gap (loop B9). When the gap in prevention and training schedule increases, time devoted to build quality culture decreases. Time devoted to suppliers decreases, increasing the pressure associated with production, which increases the stress of the workers, subsequently increasing the time devoted to urgent actions and lowering the current schedule gap (loop B10).

Quality Assurance Subsystem

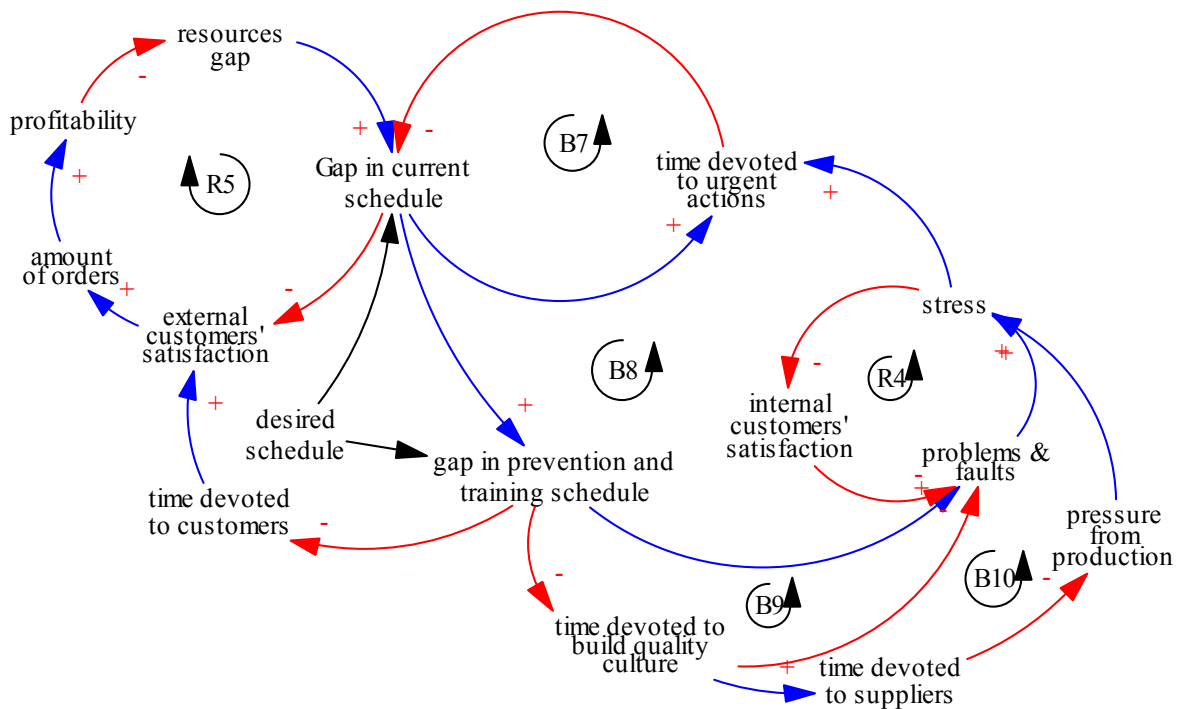


Figure 4-8: The Quality Assurance Subsystem CLD

When stress increases, internal customers' satisfaction decreases, therefore increasing problems and faults and there is furthermore increase in stress (loop R4). When the gap in current schedule increases, it lowers external customers' satisfaction, subsequently lowering the amount of orders and the company's profitability, resulting in the increase of the resources gap (the gap between the needed resources and the available resources) and finally the gap in current schedule increases even more (loop R5).

4.2.7.4 The Inventory and Logistics CLD

The first inventory and logistics subsystem causal loop diagram is represented in the following section. According to the group participant, the most useful and important loops are: R4, R5, R6, R7 and R8. This condensed inventory and logistics subsystem model is provided in Appendix J. It is used later in the full model

4.2.7.4.1 Dynamic Hypotheses for the Inventory and Logistic Subsystem

Inventory and Logistic Subsystem

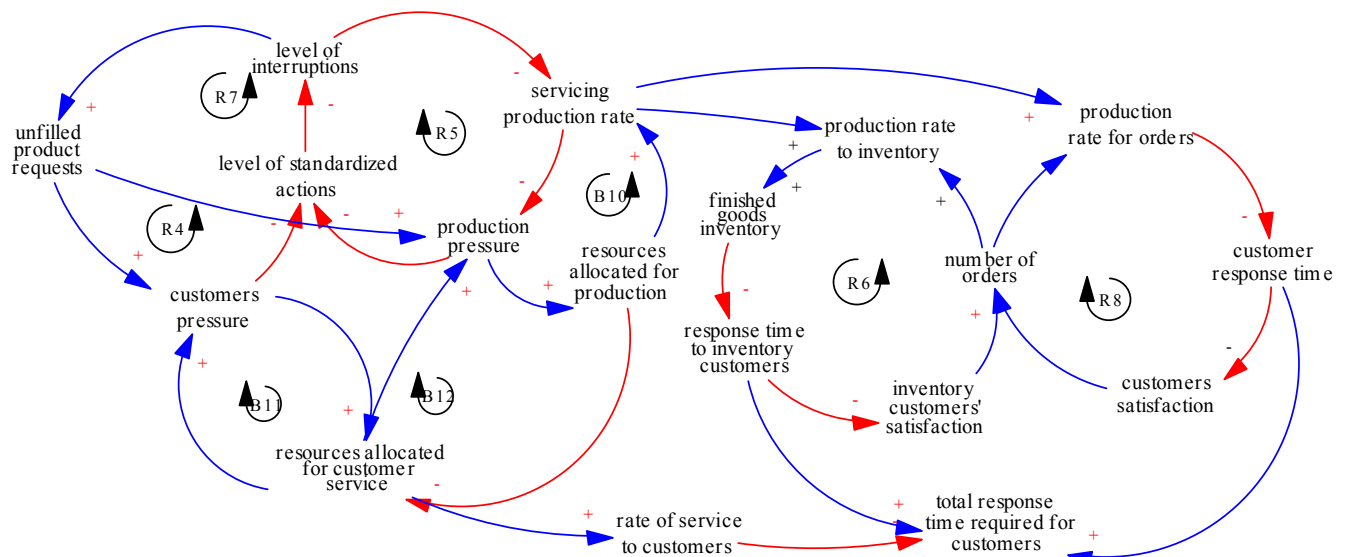


Figure 4-9: The Inventory and Logistics Subsystem CLD

The more resources are allocated to production, the higher is the rate of servicing production. When the rate of servicing production is higher, there is less production pressure to the inventory, and fewer resources are allocated to production (loop B10). The more customer pressure, the more resources are allocated for customers, which in turn lower the customer pressure (loop B11). The more production pressure, more

resources are allocated for production, which decreases the resources allocated for customers, and decreases the pressure from production (loop B12). When the unfilled request for products increases, it increases customer pressure, which causes the level of standardized actions to decrease, and therefore the level of interruptions to increase, which causes the unfilled request for products to increase even more (loop R4). When the level of standardized actions increases, the level of interruptions decreases, causing the servicing production rate to increase. This decreases the production pressure, causing the level of standardized actions to increase even more (loop R5). When the production rate for inventory (production that goes directly to inventory) increases, the amount of finished goods inventory increases too. The response time to customers that order directly from inventory is reduced, resulting in higher customer satisfaction which in turn encourages them to place orders. Consequently, a higher rate of production for inventory is required (loop R6). When the unfilled product requests increases, it increases the production pressure for products that go directly to inventory, which causes the level of standardized actions to decrease, and the level of interruptions to increase, which causes the unfilled product requests to increase even more (loop R7). The higher the number of orders, the higher is the production rate, which lowers the customer response time, and increases customer satisfaction and the number of orders even more (loop R8).

4.2.7.5 The Personal CLD

The initial personal subsystem causal loop diagram is presented subsequently. According to the group's participants, the most useful and important loops are: B10, R9, R10, and R11. Some modifications were also recommended. It included changing variables names (modifying 'organizational effectiveness gap' to 'perceived gap of organization effectiveness', 'rate of errors and defects' to 'problem & faults' and 'experience and learning opportunities' to 'level of experience & learning'). Also some variables were deleted ('actual quality work level' was included as part of the 'actual job performance level', so these variables were combined into the 'actual quality level of job performance' variable). All these changes necessitated some modifications in the loops. The final personal subsystem causal loop diagram is provided in Appendix J.

4.2.7.5.1 Dynamic Hypotheses for the Personal Subsystem

Personal Subsystem

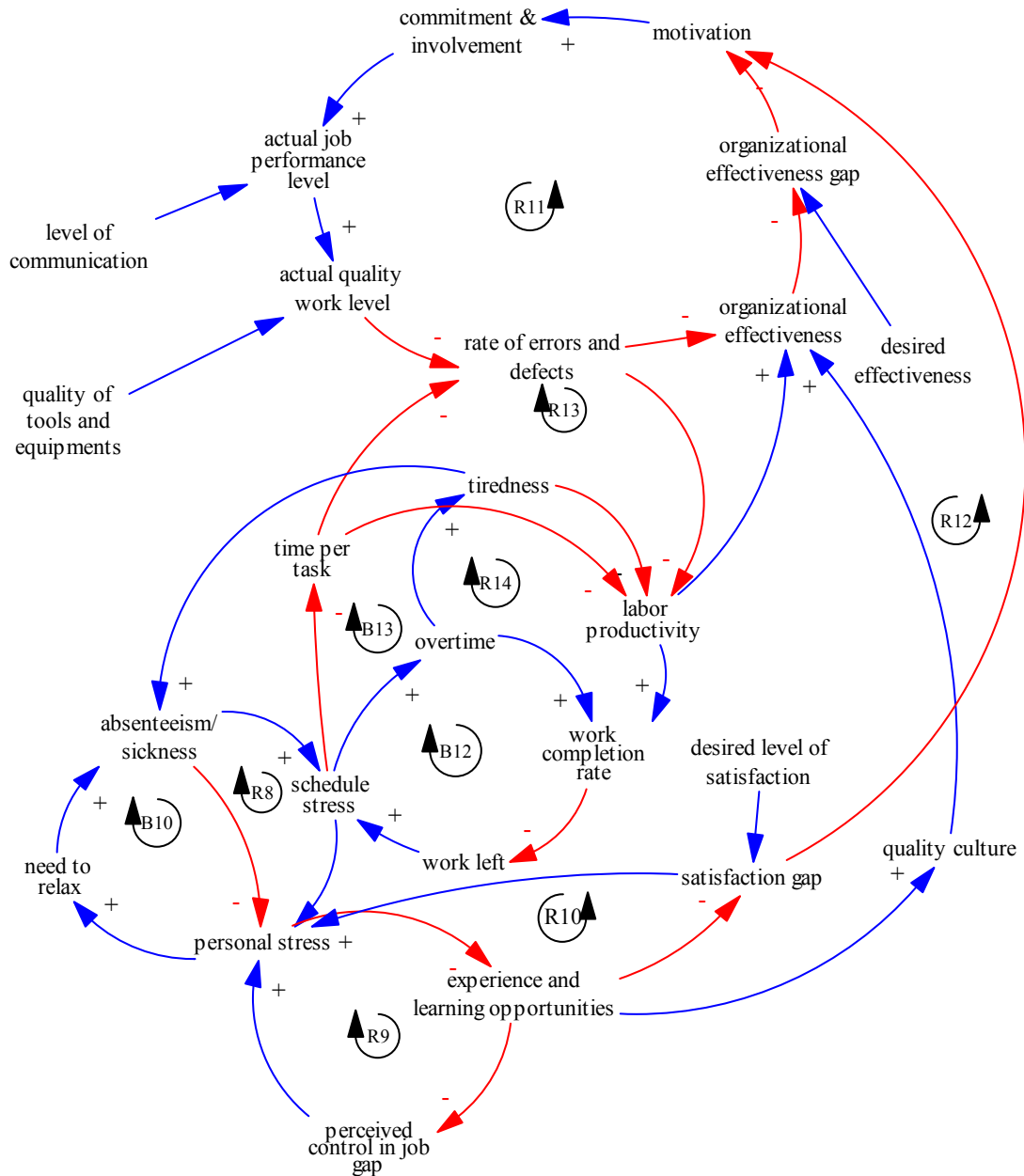


Figure 4-10: The Personal Subsystem CLD

When personal stress increases, the need to relax increases, causing for more absenteeism to occur and subsequently personal stress decreases (loop B10). When there is more work left undone, schedule stress increases, more overtime is needed, resulting in increased work completion rate, and subsequently decreasing the work left undone (loop B12). It is important to mention that overtime in the firm is limited (no more than two to

three hours are allowed per day). Otherwise, overtime increases work completion rate only to a degree, and thereafter more overtime decreases the work completion rate. When there is more work left undone, schedule stress increases; less time per task is invested, causing labor productivity to increase, which increases work completion rate, decreasing work left undone (loop B13).

When personal stress increases, the need to relax increases, more absenteeism occur, schedule stress increases, increasing personal stress even more (loop R8). When personal stress increases, experience and learning opportunities decrease, causing the Perceived Job Control gap (the gap between the desired Perceived Job Control and the actual Perceived Job Control) to increase, which increases personal stress even more (loop R9). When personal stress is low, it enables for more experience and learning opportunities to occur, which decreases the worker satisfaction gap (the gap between the desired satisfaction and the actual satisfaction), and lowers personal stress even more (loop R10). When the rate of errors and defects increases, organizational effectiveness decreases (the percentage between the quality products and the total number of products), causing organizational effectiveness gap to increase and motivation, commitment and involvement, actual job performance level, and also actual quality work level to decrease. This increases the rate of errors and defects even more (loop R11). When more absenteeism occur, schedule stress increases, increasing personal stress, experience and learning opportunities decrease, increasing the satisfaction gap, decreasing motivation, commitment and involvement, the actual job performance level, and actual quality work level. This increases the rate of errors and defects, lowers labor productivity and the work completion rate, increasing work left undone, schedule stress, overtime and tiredness, which increases absenteeism even more (loop R12). When there is more work left undone, schedule stress increases; less time per task is invested. This increases the rate of errors and defects, lowers labor productivity and the work completion rate, increasing work left undone even more (loop R13). When there is more work left undone, schedule stress increases, more overtime is needed. This increases tiredness, which lowers labor productivity, decreasing work completion rate, and increasing amount of work left undone even more (loop R14).

4.2.7.6 The Full Model CLD

A model is useful as a tool for communication and clarification, especially when the subject is complex and its behavior in the long-run is obviously different from our experience about its behavior in the present. As Forrester (1968) explained, much of our conceptualization is the essence of our mental models. Sometimes we tend to confuse our mental models with facts. As it was explained in Section 3.1.3 (p. 121), mental models are mainly based on intuition and experience and are therefore fuzzy, adaptable, incommunicable and many times inapplicable.

The full model of the organization as conceived by the workers was constructed using the ranking of the subsystems by the group members. During the process of building the full model, two inventory loops were considered irrelevant for the full model and were deleted (loops R6 and R8). The full causal loop diagram of the model contains the five subsystems: operation and production subsystem (loops: B1, B2, B3, R1 and R2), the maintenance subsystem (loops: B4, B5, B6 and R3), the quality assurance subsystem (loops: B7, B8 and B9), the inventory and logistics subsystem (loops: R4, R5 and R7) and the personal subsystem (loops: B10, R9, R10 and R11).

Figure 4-11 provides the full model. Certain variables are critical in terms of providing the links between the subsystems: the production performance gap (the gap between the production performance target and the actual production performance), which is a production subsystem variable, impacts the inventory subsystem, and the quality assurance subsystem. Problem and faults, which is a production subsystem variable, impacts the maintenance subsystem, the quality assurance subsystem and the personal subsystem. The commitment and involvement variable which belongs to the personal subsystem impact the maintenance subsystem and production subsystem. Personal stress impacts the production subsystem and the quality assurance subsystem. Time devoted to urgent actions, which is a quality assurance variable, impacts the production subsystem.

4.2.7.6.1 Dynamic Hypotheses for the Firm Conceptual Model

When the production performance gap (the gap between the production performance target and the actual production performance) increases, the pressure on employees increases, decreasing time per task, decreasing also the standardized level of

work (actually the work is not done according to the standardization), which increases the work completion rate, increases the actual production performance and decreasing the production performance gap (loop B1). When the production performance gap increases, pressure on employees increases, increasing overtime, increasing the actual production performance and this in turn decreases the production performance gap (loop B2). When the production performance gap increases, it causes the time devoted to urgent actions to increase, which in turn decreases the production performance gap (loop B3). As the level of maintenance gap (the gap between the desired preventive maintenance and the actual maintenance) increases, the rate of machine breakdowns increases, which causes the corrective maintenance tasks rate to increase (corrective maintenance is competed on the urgent maintenance tasks), which decreases the maintenance problems and decreases the maintenance gap (loop B4). As the level of the maintenance gap increases, the rate of machine deactivation increases, forcing more preventive actions. The more preventive or planned maintenance actions, the less machine wear out, the less maintenance problems occur and the level of maintenance gap decreases (loop B5). When the rate of machine breakdown is high, the total machine uptime decreases, which creates more pressure to activate the machines, which lowers the rate of machine deactivation, and the total machine uptime increases (loop B6). When the gap in current (daily) scheduled tasks (the gap between the number of completed scheduled tasks and the delayed ones) increases, the time devoted to urgent tasks increases, lowering the current schedule gap (loop B7). When the gap in current schedule increases, the gap in prevention and training schedule (the gap between what is done for prevention and training and what should have be done) gets bigger. This causes more problems and faults to happen, and causes more stress for the workers subsequently increasing the time devoted to urgent actions to and lowering the current schedule gap (loop B8). When the gap in prevention and training schedule increases, time devoted to build the quality culture decreases, causing more problems and faults to happen, and increasing workers' stress. This in turn increases the time devoted to urgent actions and lowering the current schedule gap (loop B9). When personal stress increases, the need to relax increases, causing for more absenteeism to occur, thus decreasing personal stress (loop B10).

pressure on employees increases, decreasing time per task, decreasing also the standard level of work. This causes more problems and faults to increase, which decreases productivity, decreasing the work completion rate, decreases the actual production performance, and increasing the production performance gap even more (loop R2). When more corrective maintenance tasks are provided, the machine wears out faster. When the machines wear out increases, there are more maintenance problems. More maintenance problems increase the level of maintenance gap, and also the rate of machine breakdown increases, causing more corrective maintenance tasks to be needed (loop R3). When the unfilled request for products increases, it increases the customer's pressure, which causes the level of standard actions to decrease, and therefore the level of interruptions increases, which causes the unfilled request for products to increase even more (loop R4). The higher the level of standard actions, the lower is level of interruptions, the higher is the rate of service for production, which decreases the production pressure, causing the level of standard actions to increase even more (loop R5). When the unfilled product requests increases, it increases the production pressure for goods that will be delivered to inventory, which causes the level of standard actions to decrease, and the level of interruptions to increase, which causes the unfilled product requests to increase even more (loop R7). When personal stress increases, experience and learning opportunities decrease, causing Perceived Job Control gap (the gap between the desired Perceived Job Control and the actual Perceived Job Control) to increase, which increases personal stress even more (loop R9). When personal stress is low, more experience and learning opportunities are provided, thus decreasing the employee satisfaction gap (the gap between the desired satisfaction and the actual satisfaction), and lowering even more personal stress (loop R10). When the rate of errors and defects increases, organizational effectiveness decreases, causing a decrease in the perceived organizational effectiveness and decreasing motivation, commitment and involvement, actual job performance level and finally there is a decrease in the actual quality work level. In turn, this increases the rate of errors and defects even more (loop R11).

4.3 Assumptions

The assumptions in this section are divided into two sections: assumptions dealing with the whole organization including: employees, working time, management, and the organization. The second section deals with the assumptions concerning each subsystem separately.

4.3.1 General Assumptions

4.3.1.1 Employees

The employees in the firm come from different backgrounds; consequently there is a differentiation in many aspects: their commitment to the workplace, their quality level of their work, their motivation and their satisfaction from work. However, in this model, all the employees including the managers are treated equally in all formulations' variables.

4.3.1.2 Working Time

A workday time was taken as 8.67 hours a day, which includes only the morning shift. The morning shift is the most important part of the work day and according to Sterman (2000), anything that can be deleted from the model because it does not influence the model significantly should not be included. In the model, the working time is considered the time needed in the high season which is realized in the winter and the periods of Jewish holidays in Israel, especially the holidays of New Year, (almost a month in the fall) and Passover, which is in the spring. The firm is committed to preparing special kosher food used during Passover. It takes about two months for the firm to work on this type of food. This model does not match the summer season, which is always a time of layoffs.

4.3.1.3 Management

In this model, the management is not taken into account as an endogenous variable. The relationship between different workers and the management is considered in this model as constant for all the employees, including managers, veteran employees and part time employees.

4.3.1.4 Organization

The organization is considered a stable organization, which does not go through extreme situations in this model, that may influence the system, the way it is managed, and the relation to its employees.

4.3.2 Subsystems Assumptions

4.3.2.1 Operation and Production

1. The operation and production subsystem produces products for two kinds of orders: orders that are directly for external customers and for internal customers, meaning for inventory. Every week the production plan is given to the production department. Most of it is for inventory. If there is pressure from an important external customer to finish his order, the amount of the products that was planned for inventory declines, in order to go forward with the order of the external customer. In this model there is no difference between orders for external or internal customers. The assumption is that in most cases, external customers are receiving their products from the inventory directly, which means that they have the same priority level as the inventory requirements.
2. Tasks in production are mostly planned to be executed in one day. Only a third of the tasks are planned for two to three days. In the model, a task that is not completed in one day is not modeled as a delay, but it is computed mathematically according to the number of expected open machines, and accordingly to the number of new tasks that enter the system.
3. Defective tasks enter a correction process or go back to production from the beginning. In the model, the assumption is a task cannot be defective more than once.
4. The assumption about defective production is that the gap of required machines is the main factor for defective tasks, and not the pressure of customers.
5. There is never a shortage of materials, labor, equipment and other resources for production in this model.
6. All the per day rates are constant variables.

4.3.2.2 Maintenance

1. In the model it is assumed that maintenance workers are not causing production problems. Their work is always correct.
2. Maintenance employees need to stay for overtime when it is required although the organization policy in general, is against overtime.
3. The firm uses seven main machines and thirty five beadle machines (machines that provide materials and packaging). In the model only the main machines are considered as a limit for production, because the beadle machines can be replaced with other beadle machines, in most cases.
4. The conceptual model of the maintenance subsystem includes a preventive maintenance variable. While gathering the data/information about the nature of the work the maintenance workers do, it was found out that there was no preventive maintenance at all, even though the maintenance manager was aware of its importance. Therefore it does not appear in the model. According to the maintenance manager, he does part of the preventive maintenance tasks during the set-up. He is the only one to do this, and therefore set-up tasks are included in this model. They do not appear in the conceptual model.
5. Sometimes, machines break down and the maintenance employees are not able to repair the machine by themselves. This causes the machine to wait a couple of days for a component, or for a service from outside the firm. This kind of problem is not included in this model, since it rarely occurs.
6. There is never a shortage of materials, labor, equipment and other resources for maintenance in this model.
7. All the per day rates are constant variables.

4.3.2.3 Quality Assurance

1. It is assumed that customers' satisfaction from the quality of products is an exogenous factor in this model, and therefore is not included in this model.
2. All the per day rates are constant variables.

4.3.2.4 Inventory and Logistics

1. The assumption is that inventory employees do their work correctly. Defects and interruptions are the result of the pressure from production and from external customers waiting for their products.
2. In the model, the assumption is that there is never a shortage of materials in the inventory.
3. The production pressure to deliver products to inventory and the customer pressure for products in inventory are identical, and have the same impact on the interruption tasks in inventory.
4. There is never a shortage of materials, labor, equipment and other resources for inventory in this model.
5. All the per day rates are constant variables.

4.3.2.5 Personal

1. I assume that for all the variables that describe the employees' feelings in the organization including: work satisfaction, stress, organization commitment, and Perceived Job Control have a random distribution (with rectangular distribution).
2. The firm's employees receive a bonus if they are not absent from work. The workers are seldom absent. The assumption in the conceptual model is that when employees are stressed, they choose to take a leave of absence as being sick, which helps them to relax and to return to work less stressed, This is included in the quantitative model, but with values that have a little impact on the model.
3. All the per day rates are constant variables.

4.4 The Stock and Flow Structures

The conceptual model (Figure 4-11, p.194) expresses the group's mental model of the system. In order to understand the dynamic behavior of the system, we resort to the use of formal models which have, as explained in Section 3.1.3 (p. 121), two advantages over informal models. First, formal models are explicit and therefore they are communicable. The formal model exposes the decision-makers' assumptions about the

problem, and therefore they can be criticized, experimented and reformulated. This cannot be done in the case of informal models.

A formal model uses parameters and variables. Parameters and variables enable the formation of equations that describe the relationship between the parameters and the variables in feedback loops and create the specific dynamic behavior of the virtual model. Parameters are constant values of the model. Variables are functions of time or are functions of other variables and they may change as a result of the behavior of the model. In a system dynamics model, the key variables are considered as level variables or stocks. These variables represent the accumulation, which occurs at a certain rate over a certain period of time during the time horizon. The in-flow and out-flow from the stock are the rates entering the stock and exiting the stock.

In this research, after the group-model-building team members finished building the conceptual model, the group decided which stocks and flows are needed for the model in order to be able to formulate the quantitative model. (Appendix G)

In order to formulate the entire stock and flow diagram, the modeling process started with building each one of the subsystems separately as a stock and flow diagram, collecting data and information from the associated workers, examining its behavior by the related workers and managers and making all modifications until it was approved by all the related participants.

The entire stock and flow diagram was built by connecting all the subsystems together, including relationships and loops that connected parameters and variables from different subsystems and the addition of stocks and relationships as required. Building the entire model is explained in Section 4.4.2.6 (p. 236) (explanation about stocks and flows, see Section 3.3.3.2 (p. 128)).

First, I introduced the full model as the group converted the conceptual model to a formal quantitative model. In order to achieve the most plausible list of key variables that would be considered as stocks, the group members were divided in pairs. Each pair had to choose the most important variables. Then, the group was divided into two sub-groups, and each sub-group had to repeat the selection process. The third phase was a convergent discussion with all the group participants who made the final decision and drafting the list of the most critical variables. (Appendix F) The stock and flow diagram was prepared for

the next session, in which the group participants had to accept or to express their opinion about the model. According to their comments, the model diagram was modified until it was approved by all the group members. (Appendix G) I will first describe the full stock and flow model that was built by the group, and later the full model that was built after the subsystems models were quantified.

4.4.1 The First Full Stock and Flow Structure

The followings are the stocks and flows in this model according to the group model building decision:

The Production Subsystem: The most fundamental stock in production is the open tasks that accumulate between the tasks that enter the production and those that have been completed. This stock is partitioned into two stocks: the stock of tasks that are produced using the required standard process, and the stock of production tasks, which are performed with problems and faults (loops B1, B2, B3 and R1).

The Maintenance Subsystem: Maintenance activities primarily include daily corrective machine tasks, weekly treatment of machine breakdowns, and preventive maintenance tasks. These are the three stocks in the maintenance subsystem (loops B4, B5 and R3).

The Quality assurance Subsystem: Quality's activities include daily open tasks in quality, the prevention and training tasks and the quality culture open tasks like management by facts or learning (loops R2 and R7).

The Inventory and logistics Subsystem: Inventory deals with two kinds of services: services for production and services for external customers. As long as no pressure exists from production or from customers, the work in inventory is done according to standard methods. This leads to four stocks in the inventory subsystem: The open tasks necessary for production, the stock of customers waiting for service, the level of interruptions and inventory standard level of actions (loops B6 and B7).

The Persona Subsystem: All the factors that influence the health of the employee are defined as stocks: Satisfaction, personal stress, Perceived Job Control and commitment & involvement. Furthermore, sickness is also defined as stock (loops B10, R6, R9, R10 and R11).

The Firm's Stock and Flow Model

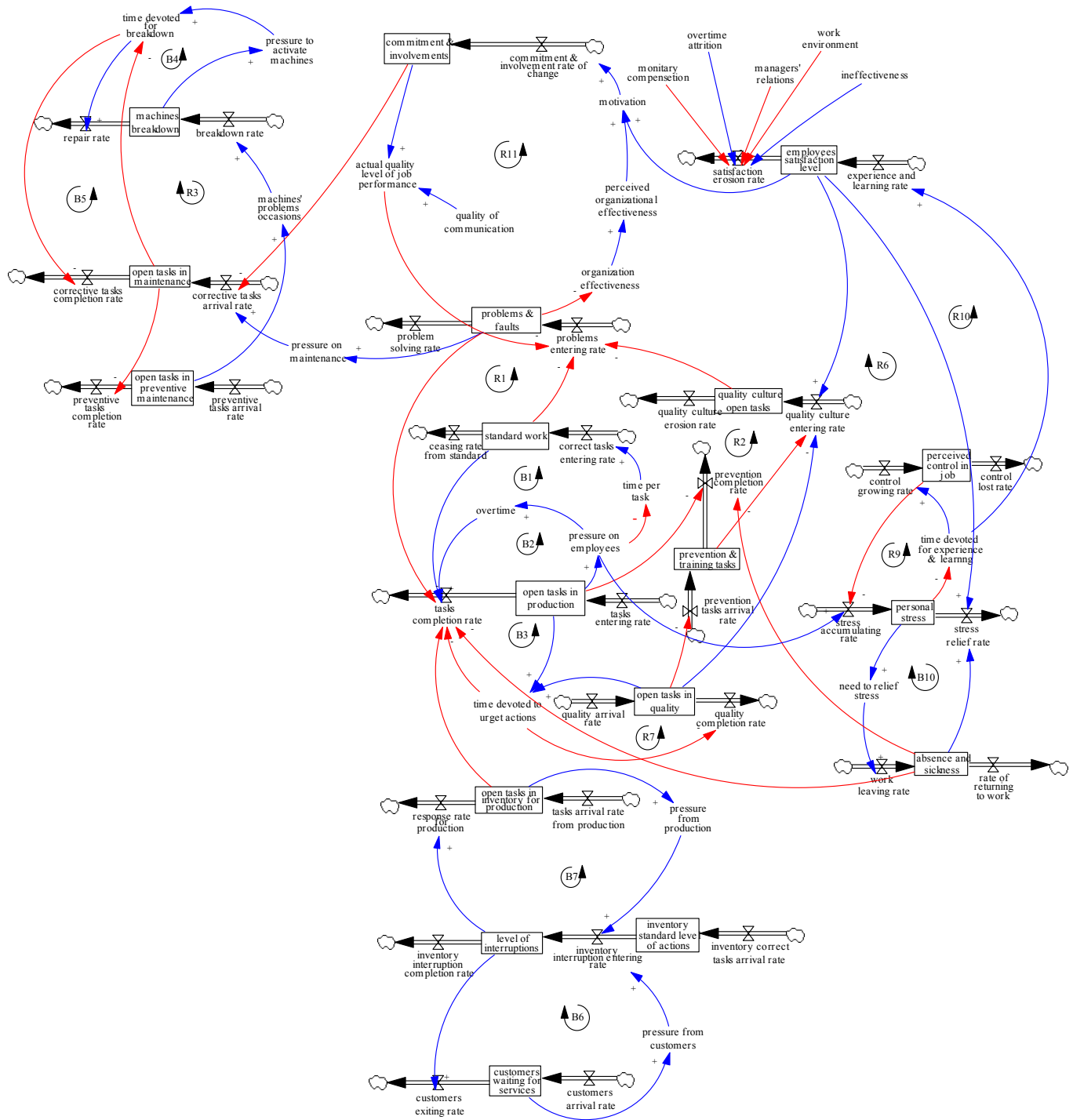


Figure 4-12: The Firm's Initial Stock and Flow Model

The dynamic hypotheses for this model are presented in Appendix G. Building the model step by step included gathering data, constructing relationships between variables and parameters, and formulating their equations. This process entailed many changes to the initial full model, which is seen in the following discussion.

4.4.2 Building the Second Full Stock and Flow Structure

Building the full stock and flow structure including parameters and variables had started by building each subsystem separately and making sure that it behaves as expected. In the following sections, I will introduce each stock and flow subsystem model, with the data that was gathered about its parameters, variables and its behavior.

In order to get a better insight, the results of the behaviors will be exhibited in this section for one year. Appendix L will exhibit the results for three years, the time horizon (the behavior of the one year results are similar to those of three years, but are clearer in graphs that depict them). The subsystems are: Section 4.4.2.1 Production and Operation (p. 203), Section 4.4.2.2 Maintenance (p. 208), Section 4.4.2.3 Quality Assurance (p. 218), Section 4.4.2.4 Inventory and Logistics (p. 222), Section 4.4.2.5 Personal (p. 228) and in Section 4.4.2.6 the full model (p. 236) is introduced.

4.4.2.1 The Production and Operation Stock and Flow Model

The production subsystem produces the required products according to orders. The production manager is responsible each day to check the orders waiting to be completed next and whether there are no finished products in the inventory. According to the collected information, the manager prepares the list of required production for the day, which serves as their daily work plan.

The production department is supposed to perform all the tasks according to the accepted standards (loop B3). The number of available machines limited the department's ability to stay on time with the rate of orders, which resulted in frequent pressure on the employees to finish the tasks earlier. This means that instead of performing according to the standards, the employees were encouraged to 'cut corners' (*Out of Order Tasks Completion Rate*). This caused problems and malfunctions. Most of the tasks (approximately ninety percent) with problems complete the production process by using solutions for the problem (*Problem Solution Rate*). On average, ten percent of these

problematic tasks require to start the production process over again (*Tasks Going Back to Production*).

Operation and Production Model

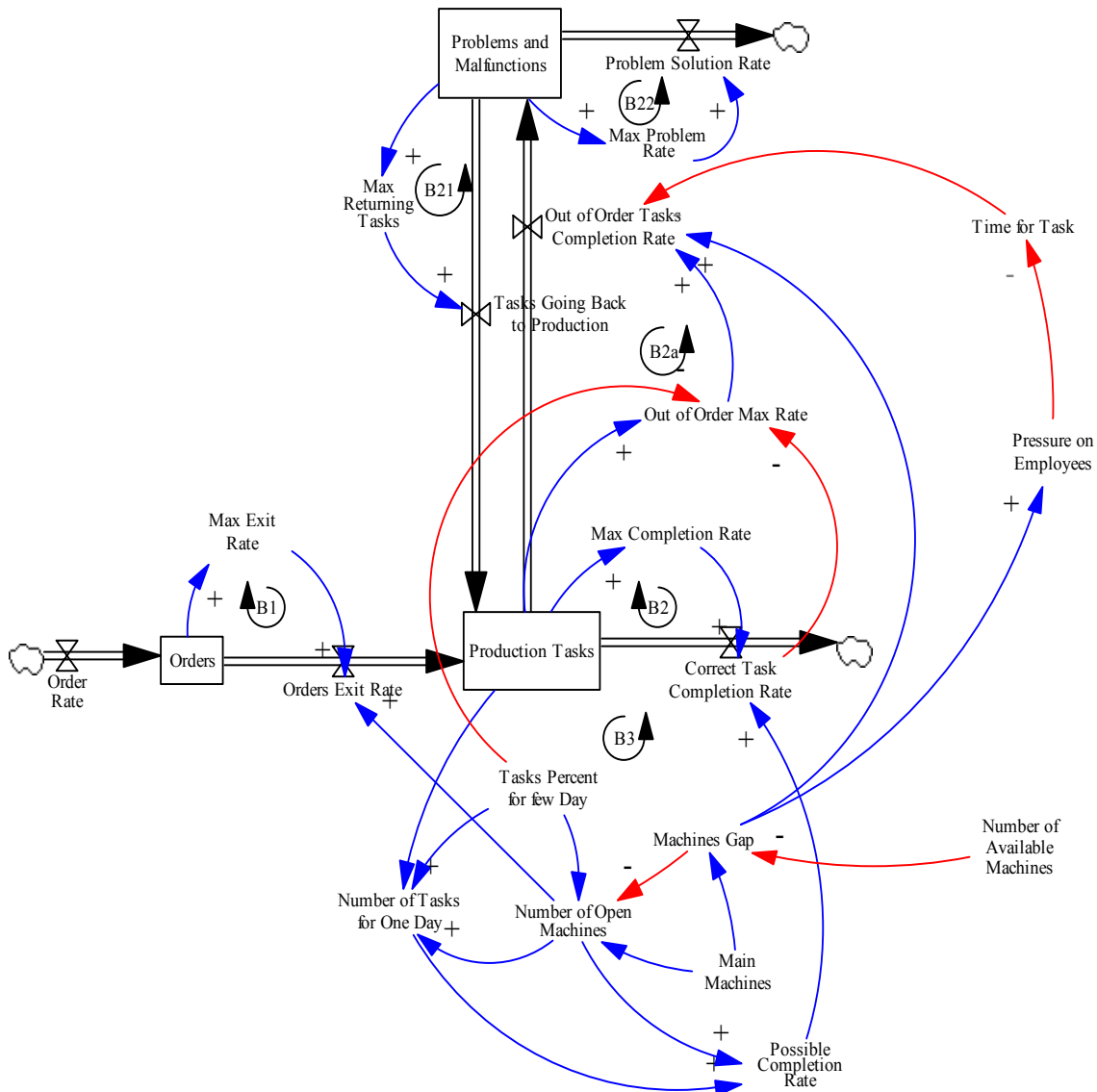


Figure 4-13: The Production and Operation Stock and Flow Diagram

4.4.2.1.1 Stocks

Production and operation model includes three stocks: *Orders* is the stock of the orders that are waiting to enter production. These orders are received from external customers and also from internal orders to replenish inventory. *Production Tasks* is the stock of the orders that entered into production in order to be completed. The number of

tasks that can enter production depends on the number of the open machines. *Problems and Malfunctions* is the stock of those tasks that were not done correctly and need special treatment or repair. Some of the tasks (in average, ten percent) of the *Problems and Malfunctions* return to *Production Tasks*, as explained before.

4.4.2.1.2 Parameters

There are seven main machines working full time. This parameter constraints how many tasks can enter production. The length of the workday is considered 8.67 hours. Overtime is considered as a distinct variable. About ten percent of the problems and malfunctions tasks return back to production from the beginning of the simulation.

4.4.2.1.3 Gathered Data and Initial Conditions

1. Order rate is between one and four orders per day.
2. The exit order rate is the same as the arrival rate for production. This number depends on the number of open machines (between 0-7).
3. The correct task completion rate depends on the number of open machines. If the number of open machines is greater or equal to the number of tasks entering production, this rate will be identical to the number of tasks entering production times a value between 0.35-0.7 which is the percentage of tasks that are completed each day. If the number of machines is less than the number of tasks entering production, then the completion rate depends the maximum number of open machines, since there are tasks that take more than one day.
4. The out-of-order tasks completion rate happens when there are more machines required than what is available (meaning that there is a gap between the number of open machines and required machines). This causes pressure on employees to finish their work faster, thus compromising the correctness of production. The out-of-order task completion rate depends on the gap between the required machines and the available machines. This gap causes the employees to invest less time in their production.
5. The machines gap causes pressure on employees. The relationship between them is a non-linear one.

6. The completion time for tasks becomes shorter, as the pressure on employees becomes higher. It is a non-linear relationship. In general, the time devoted for a task is one day.
8. The code for this subsystem model along with the equations are presented in Appendix K.

4.4.2.1.4 Dynamic Hypotheses for Production and Operation

As mentioned before, the production and operation subsystem includes three stocks. In order to ensure that no stocks become negative, each stock is connected to a loop that examines the maximum allowed outflow rate (Sterman, 2000, p. 863). The real outflow rate is limited by the maximum rate (loops B1, B2, B2a, B21 and B22).

When the number of Production Tasks increases, the Number of Tasks for One Day increases, and therefore the Possible Completion Rate and the Correct Task Completion Rate increase, decreasing the amount of Production Tasks (loop B3).

4.4.2.1.5 Results

Production Tasks:

According to data, the daily task arrival rate depends on the number of open machines. Also, the number of tasks that are supposed to be completed in one day ranges uniformly between 0.35 -0.7 of the arriving tasks. This causes the stock of production tasks to oscillate between three and six per day, as long as the production actions are not interrupted, as we can see in Figure 4-14. According to Figure 4-14, the *Correct Task Completion Rate* (between two and five tasks per day) is more than the *Out-of-Order Tasks Completion Rate* (between zero and one tasks per day).

Production one year behavior

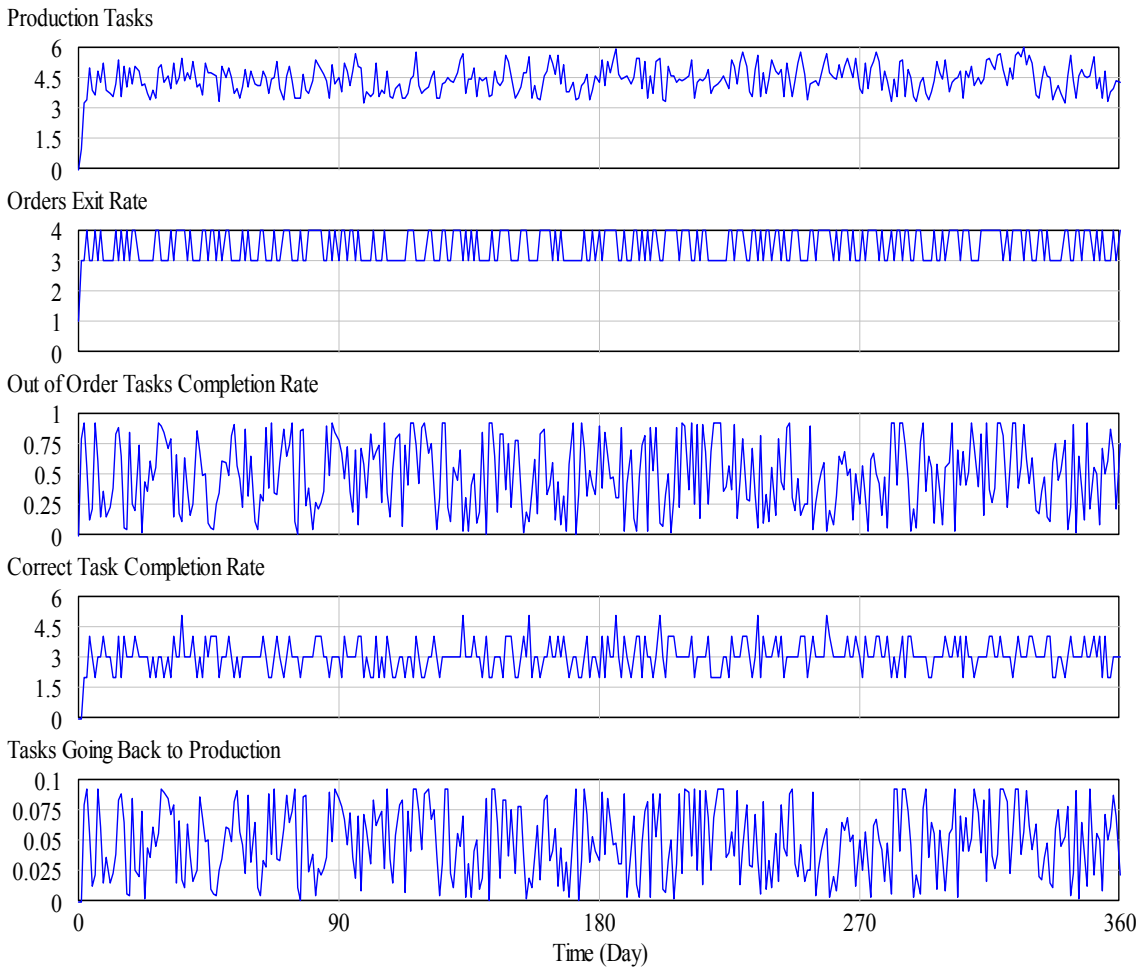


Figure 4-14: Production Tasks Stock Behavior over One Year

Orders:

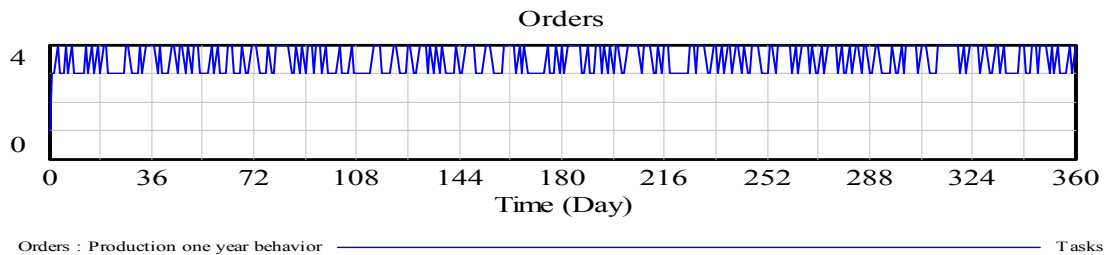


Figure 4-15: Orders Behavior over One Year

According to Figure 4-15, the daily *Orders* stock fluctuates between three order and four orders, which are waiting to enter production. In the real world, there are occasions of more daily orders waiting for production. The model is limited in taking into account extreme conditions that are possible in the real world.

Problems and Malfunctions:

According to Figure 4-16, the number of tasks that accumulate in the *Problem and Malfunctions* stock (instead of being completed according to standard methods) are between zero and one task per day.

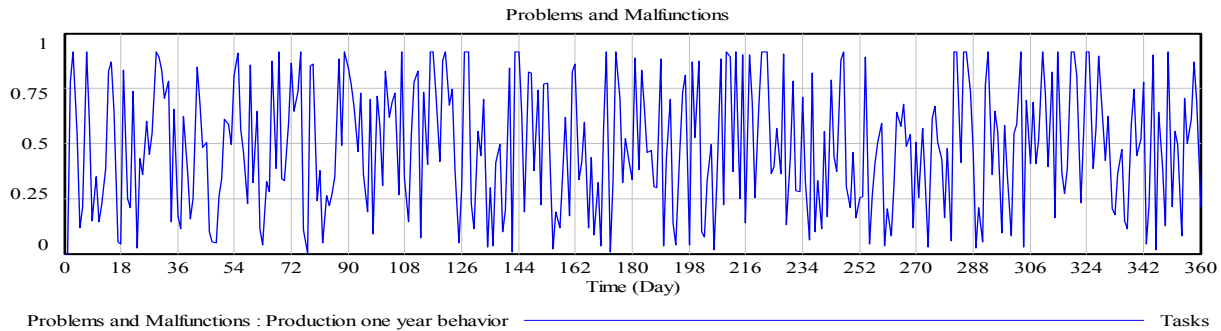


Figure 4-16: Problem and Malfunctions Stock Behavior over One Year

Pressure on Employees

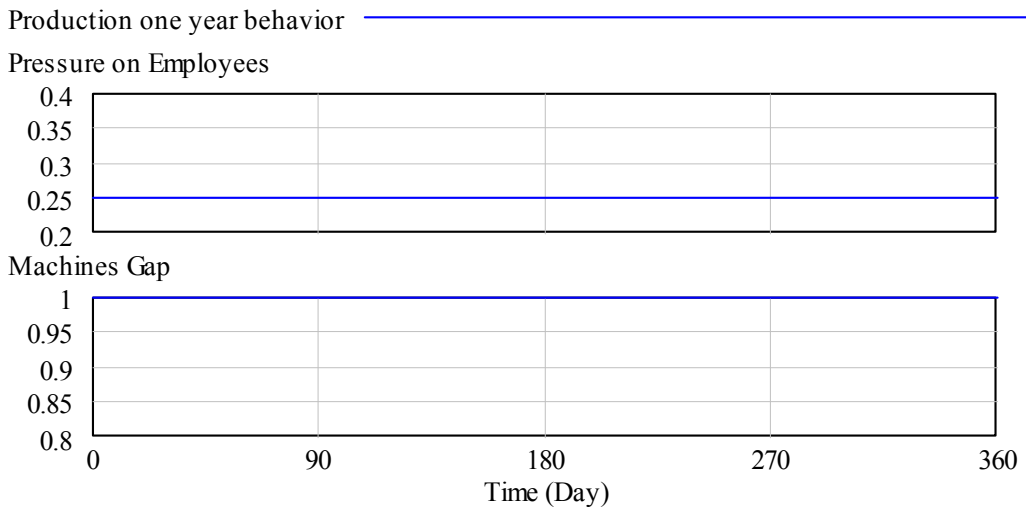


Figure 4-17: Pressure on Employees Stock Behavior over One Year

Pressure on Employees in the subsystem is influenced only by the unavailable machines. Since the *Machine Gap* in this simulation is always one machine, the *Pressure on Employees* is constant as 0.25 (Figure 4-17). This behavior is changed when the full model is simulated.

4.4.2.2 The Maintenance Stock and Flow Model

Maintenance plays a crucial role in daily production. Work cannot be done properly without the cooperation of the maintenance employees who are responsible for the machines' setup and corrective maintenance tasks in the course of the day. The

maintenance department consists of two permanent workers (one of whom is the manager) and an additional temporary worker who is actually a production worker who helps in case there is a need in the department. The work schedule is not all devoted to maintenance but to other tasks as well. Tending to the broken down machines is secondary to the setup of machines and performing corrective tasks. The only person dealing with the repair of broken down machines is the maintenance manager. The workers along with the manager have to work overtime only when there are serious problems with the machines. Preventive maintenance is hardly completed so as to prevent frequent machines' breakdowns.

The subsystem calculates the time required for maintenance. Loops B9, B10 and B11 deal with the corrective tasks. Loop B9 deals with the time needed to complete the corrective tasks and if necessary, it includes the completion rate required to decrease the number of open corrective tasks. Loop B10 includes the time required for maintenance and calculates the number of workers needed to complete the corrective tasks. In loop B11 the shortage of time and workers is examined as well as if there is a need for overtime to complete the maintenance tasks. Loop B13 deals with setup done solely by the maintenance manager. The loop checks the time required by the manager to complete his tasks. During this time, he cannot tend to the broken down machines. Loops B8 and B8a deal with broken down machines (main machines and the beadle machines). Loop B14 connects all the loops related to the treatment of broken down machines, maintenance of machine and machine setups. The less time spent on one task requires less time to complete the other tasks.

4.4.2.2.1 Stocks

Presently, the main target of maintenance is to provide service to the production workers with all the machine malfunctions. This is the stock of *Corrective Maintenance Tasks*. When a machine is designated to produce a different product, the machine needs to be set-up. This is the *SetUp Tasks* stock.

As it is mentioned in Section 4.3.2.2 (p. 198), there are seven major machines in production and thirty five beadle machines. Therefore there are two kinds of breakdown stocks: *Machine Breakdown Open Tasks* which represents the breakdown of the major machines and is mostly important for the ongoing production, and the *Beadle Machines*

Breakdown Open Tasks, which are very frequent during the day, since the beadle machines are large in number and are prone to break down more often.

4.4.2.2.2 Parameters

For maintenance, there are seven main machines and thirty five beadle machines (these machines perform activities like; material filling, packaging etc.). Set-up tasks are required only for the seven main machines. As far as repair, it involves all machines (main and beadle). The length of the workday is considered 8.67 hours. The number of work days per week is five.

4.4.2.2.3 Gathered Data and Initial Conditions

1. The average time per corrective maintenance task is uniformly distributed randomly between three quarters of an hour to three hours.
2. The average time for completing a machine breakdown repair is uniformly distributed randomly between one hour and eight hours.
3. The average time for completing a breakdown of a beadle machine is distributed randomly between half an hour and five hours.
4. The beadle machines' breakdown is uniformly distributed randomly between one machine per week and four machines per week.
5. The information about the daily schedule of the maintenance workers included: training time (uniformly randomly distributed between zero and two hours per day) and time spent in meetings (uniformly randomly distributed between zero and a third hour per day). The rest of the day is dedicated either to corrective tasks or to breakdown tasks.
6. The corrective maintenance tasks arrival rate depends on the following: The standard time for the corrective maintenance tasks arrival rate which is between twenty to thirty two tasks per day uniformly randomly distributed, and on the effect of diligence (the more a worker is diligent, fewer corrective maintenance tasks occur). The effect of diligence on corrective maintenance tasks arrival rate is assumed to be an exponential decay function.
7. The corrective maintenance task completion rate depends on the following: Time required for corrective maintenance tasks, which is the total number of corrective maintenance tasks multiplied by the average time per a corrective

maintenance task, against the maximum possible time for corrective maintenance tasks available for the workers, which depends on the number of workers available for maintenance, the time allotted for these tasks and the overtime which is needed to complete them.

8. Machine breakdown rate runs between zero and two per day uniformly randomly distributed. According to the workers, there is also a connection between the open corrective maintenance tasks and the breakdown rate of machines. It was decided that breakdown rate is on average one percent of the open corrective maintenance tasks.
9. The level of importance of the different types of maintenance tasks is as follows. For the manager first priority goes to the set-up tasks second priority is given to the corrective maintenance tasks and last priority is given to the machine breakdown tasks. For the workers the first priority is given to the corrective maintenance tasks and the second priority is given to the machine tasks.
10. The time dedicated for machines that breakdown is first dedicated to the major machines and only if time is left – to the beadle machines.
11. The set-up arrival rate is between zero and five machines per day randomly distributed.
12. The set-up completion rate depends on the number of set-up open tasks, and the maximum time the manager can devote for set-up, since he is the only worker that deals with set-ups.
13. The model code along with equations for this subsystem is presented in Appendix K.

4.4.2.2.4 Dynamic Hypotheses for Maintenance

In order to ensure that no stocks will become negative, each stock is connected to a loop that examines the maximum allowable outflow rate (Sterman, 2000, p. 863). The real outflow rate is limited by the maximum rate. The following loops ensure the non-negative of stocks: B12, B17 and B18.

MAINTENANCE MODEL

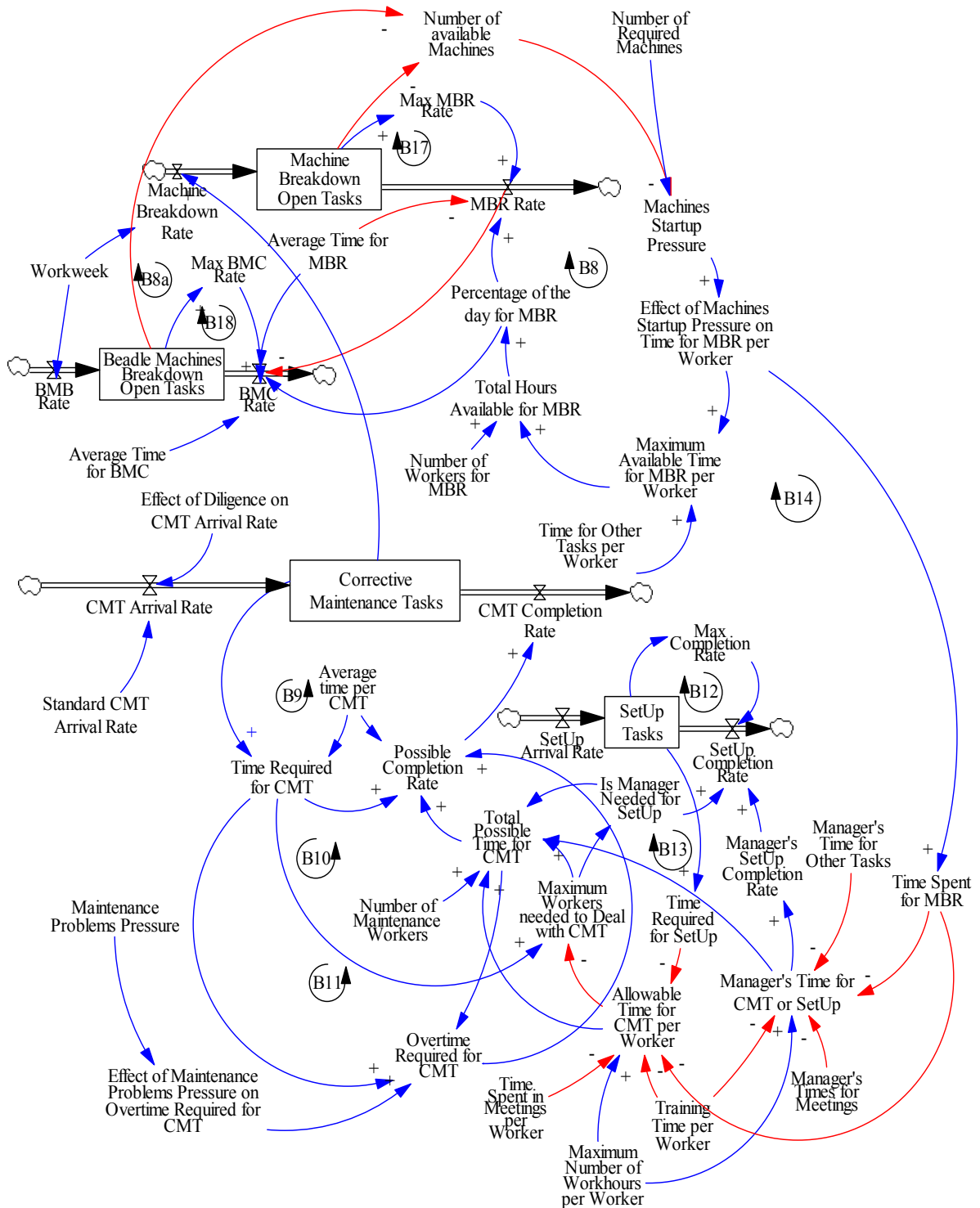


Figure 4-18: The Maintenance Stock and Flow Diagram

The more *Beadle Machines Breakdown Open Tasks* there are, the less are the *Number of Available Machines*. This cause the *Machines Startup Pressure* to become higher (each machine needs about one to four beadle machines in order to work). This affects the *Time for Machine Breakdown Repair (MBR) per Worker* (*Effect of Machines Startup Pressure on Time for MBR per Worker*). It causes the *Maximum Available Time for MBR per Worker* to grow, which maximizes the *Total Hours Available for MBR*. This defines the *Percentage of the Day for MBR* and impacts positively the *BMC (Beadle Machine Completion) Rate*, which lowers *Beadle Machines Breakdown Open Tasks* (loop B8a).

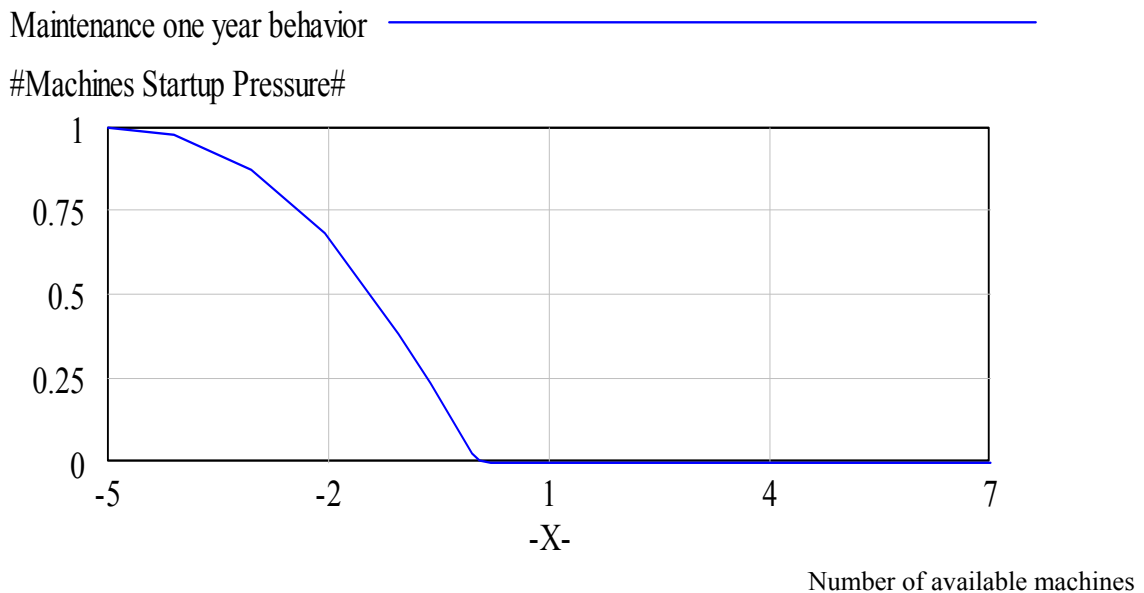


Figure 4-19: Machines Startup Pressure as a Function of the Number of Available Machines

Machines start up pressure is caused by the gap between the *Number of Required Machines* and the *Number of Available Machines*. This pressure gets lower gradually, as soon as the gap between the required machines and the available machines is smaller. The pressure is zero, when no broken machines exist.

The *Effect of Machines Startup Pressure on Time for MBR (Machine Breakdown Repair) per Worker*:

When the pressure to startup machines begins, the time for repairing the breakdown machines goes up immediately. When pressure continues, the time available for repair decreases, until it reaches a whole day.

#Effect of Machines Startup Pressure on Time for MBR per Worker#

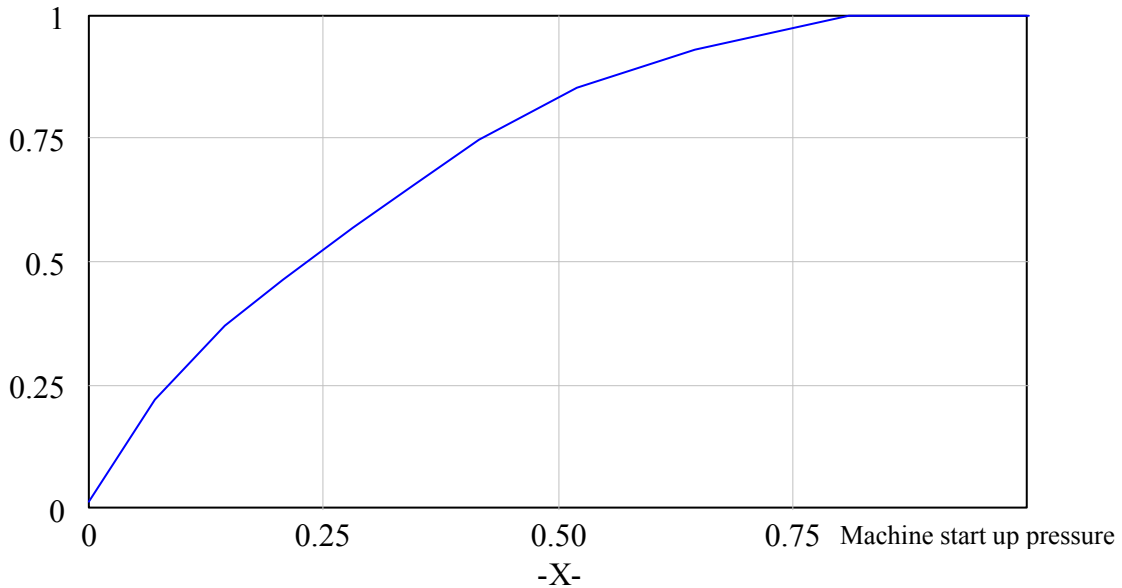


Figure 4-20: The Effect of Machines Startup Pressure on Time for MBR (Machine Breakdown Repair) per worker

When there are more *Machine Breakdown Open Tasks*, there is less *Number of Available Machines*. This causes the *Machines Startup Pressure* to be higher, which increases the *Time for MBR (Machine Breakdown Repair) per Worker*. It causes the *Maximum Available Time for MBR per Worker* to grow, which maximizes the *Total Hours Available for MBR*. This defines the *Percentage of the Day for MBR* and impacts positively the *BMR Rate* and this in turn lowers the *Machines Breakdown Open Tasks* (loop B8).

When there are more *Corrective Maintenance Tasks*, more *Time is Required for CMT (Corrective Maintenance Tasks)*. This means that the *Possible Completion Rate* needs to be higher which impacts the *CMT Completion Rate*. The higher the *CMT Completion Rate* is the lower is the stock of *Corrective Maintenance Tasks* (loop B9). This loop models whether the time required for CMT is available in order to complete the tasks, otherwise it requires overtime - loop B11.

Corrective Maintenance Tasks is the stock that is accumulated by the *CMT Arrival Rate*, which is influenced by the level of diligence of the employees. This effect is described in Figure 4-21.

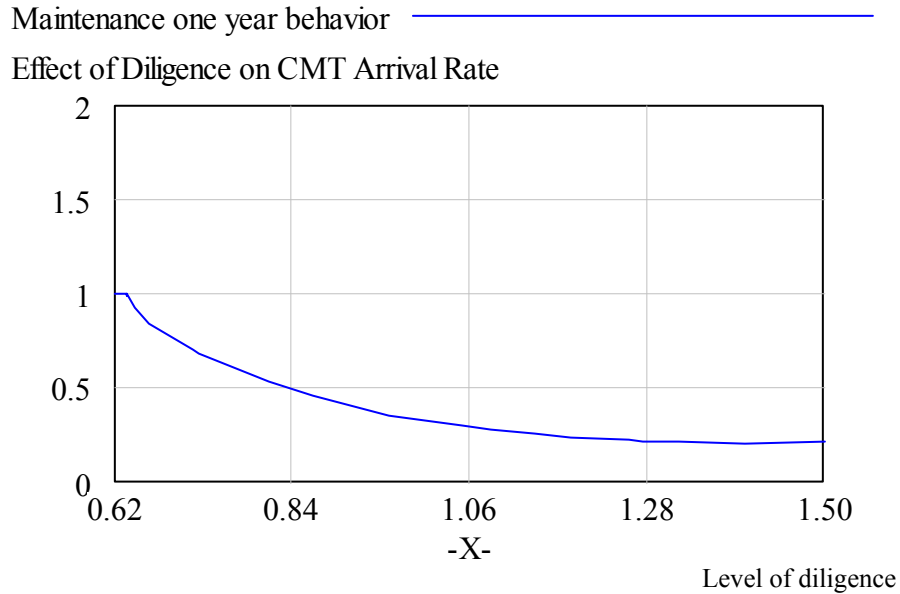


Figure 4-21: The Effect of Diligence on the Corrective Maintenance Tasks Arrival Rate

The effect of diligence on the corrective maintenance tasks rate is as follows. The number of tasks entering for correction becomes higher as the diligence becomes lower. According to the maintenance manager, the minimum value for diligence level is 60 percent and maximum is 150 percent.

When there are more *Corrective Maintenance Tasks*, more *Time is Required for CMT* (Corrective Maintenance Tasks). This increases the *Maximum Workers needed to Deal with CMT*, and increases the *Total Possible Time for CMT* and the *Possible Completion Rate*, which increases the *CMT Completion Rate*. The higher the *CMT Completion Rate* is the lower is the *stock of Corrective Maintenance Tasks* (loop B10).

When there are more *Corrective Maintenance Tasks*, more *Time is Required for CMT* (Corrective Maintenance Tasks). This causes for more *Overtime Required for CMT*, which influences the *Possible Completion Rate*, which impacts the *CMT Completion Rate*. The higher the *CMT Completion Rate* is the lower is the *stock of Corrective Maintenance Tasks* (loop B11).

The *Effect of Maintenance Problem Pressure on Overtime Required for CMT* is described in Figure 4-22.

#Effect of Maintenance Problems Pressure on Overtime Required for CMT#

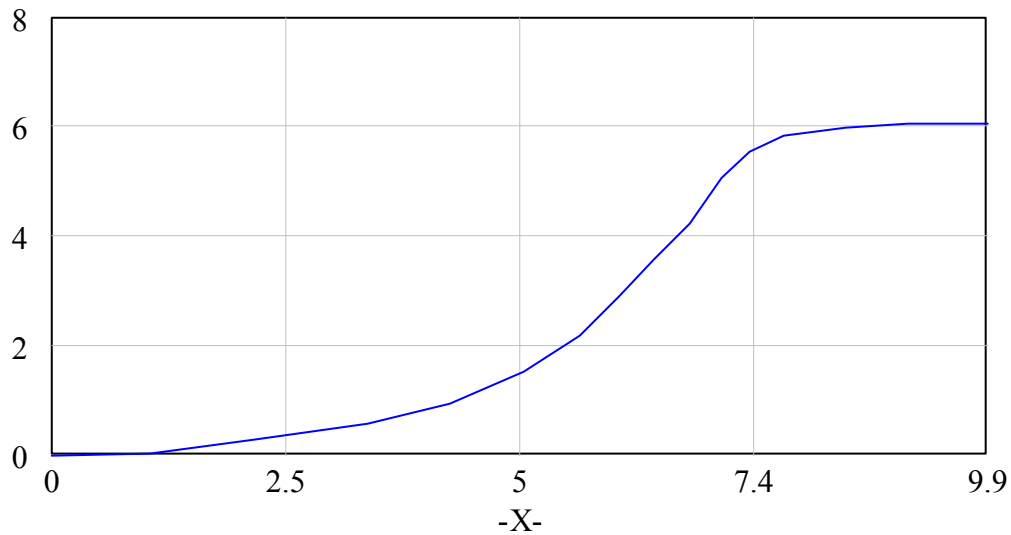


Figure 4-22: Effect of Maintenance Problems Pressure on Overtime Required for Corrective Maintenance Tasks

The effect of pressure associated with maintenance problems on the overtime required for corrective maintenance tasks grows faster at the beginning, and then slows down, but never exceeds six hours a day, no matter how high the pressure is.

The higher the number of *SetUp Tasks* the more *Time is Required for Setup*. This decreases the *Allowable Time for CMT per Worker*, and increases the *Maximum Workers needed to Deal with CMT*. In order to increase the maximum number of workers to deal with CMT, the question that arises is whether the *Manager Is Needed for Setup*. When the answer is negative, than the *Setup Completion Rate* is higher which lowers the *Setup Tasks* (loop B13).

The higher the *Corrective Maintenance Tasks*, the higher is the *Machine Breakdown Rate*, which causes more *Machine Breakdown Open Tasks*. This lowers the *Number of Available Machines*, and causes the *Machines Startup Pressure* to increase. The *Effect of the pressure associated with Machines Startup on the Time for MBR* (Machine Breakdown Repair) *per Worker* is higher and therefore, the *Time Spent for MBR* increases, and the *Allowable Time for CMT per Worker* decreases. The *Maximum Workers needed to Deal with CMT* increases and therefore the answer for *Is Manager Needed for Setup* – will probably be: "Yes". In this case, the *Total Possible Time for*

CMT increases, and the *Possible Completion Rate* increases as well (for CMT), which increases the *CMT Completion Rate*, and decreases the *Corrective Maintenance Tasks* (loop B14).

4.4.2.2.5 Results

Corrective Maintenance Tasks:

The amount of *Corrective Maintenance Tasks* usually is around thirty five tasks, but several times it grows up above fifty. This however does not happen in the first three months.

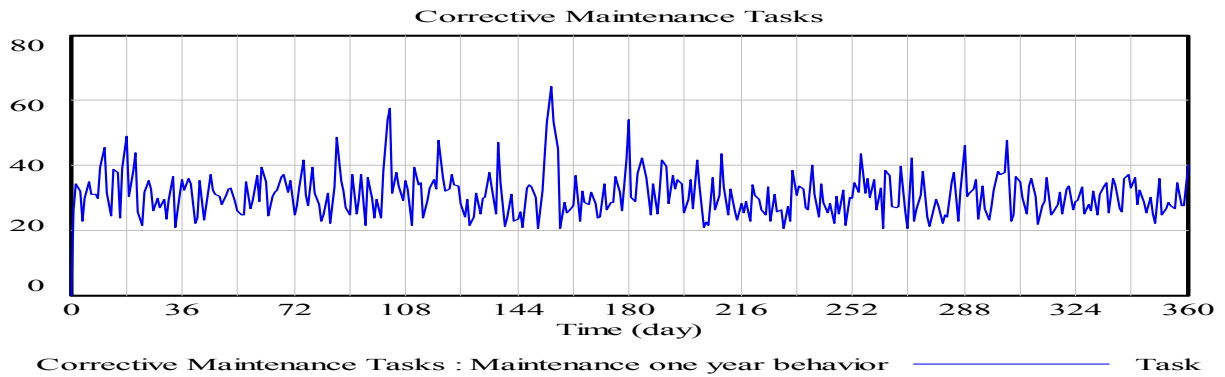


Figure 4-23: Corrective Maintenance Tasks Behavior over One Year

Set-Up Tasks:

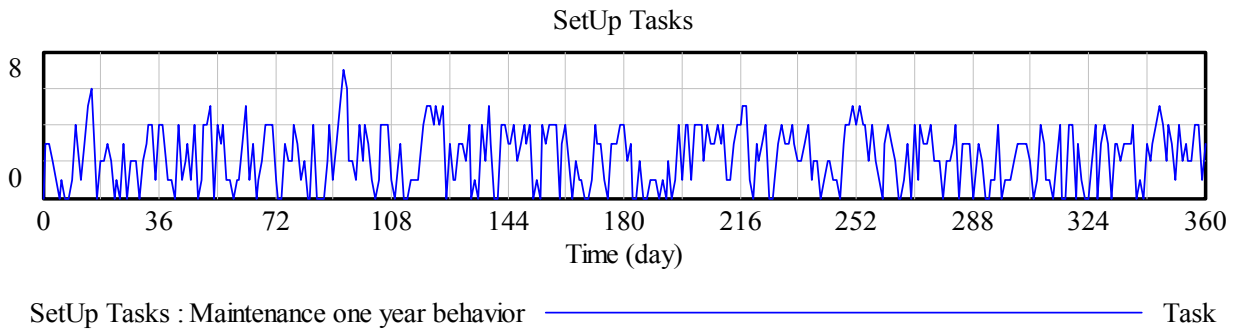


Figure 4-24: Set-Up Tasks Behavior over One year

In most occasions, the daily *SetUp Tasks* is between zero and four tasks, but over the year there are cases, when it is above that. Rarely, it is above six tasks. According to maintenance manager, *Set-Up Tasks* are rarely above four tasks.

Machine Breakdown Open Tasks:

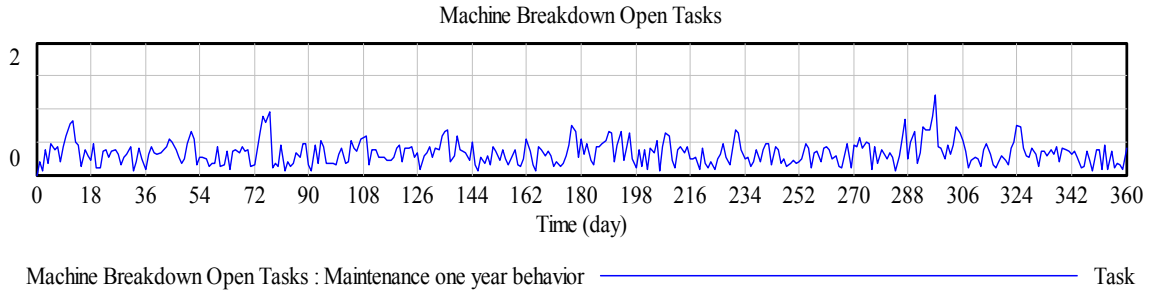


Figure 4-25: Machine Breakdown Open Tasks Behavior over One Year

According to the maintenance manager, machines’ breakdown rate is between zero and two per week. Figure 4-25 confirms this behavior.

Beadle Breakdown Open Tasks:

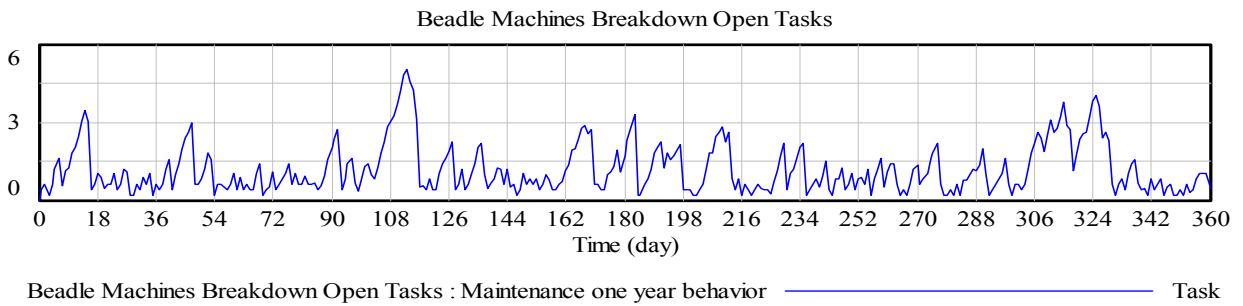


Figure 4-26: Beadle Machines Breakdown Open Tasks Behavior over One Year

Beadle machines breakdown is more frequent than major machines, and they also take second priority when treating them, as it is explained in Section 4.4.2.2.3 (p. 210), the time dedicated for breakdown machines is first dedicated to the major machines and only if time is left – to the beadle machines. Therefore, the number of broken beadle machines rises up to five machines, which is more than the breakdowns associated with the major machines.

4.4.2.3 The Quality Assurance Stock and Flow Model

Being in the food industry, the firm is committed to manufacture in accordance to all the regulations and requirements of quality assurance and safety governing this industry. Therefore, the firm has been granted HACCP (Hazard Analysis and Critical Control Point) certification, which is a systematic approach to identifying and controlling hazards (microbiological, chemical or physical) that pose a danger to the preparation of safe food (<http://www.haccpweb.com>). It also received GMP (Good Manufacturing

Practice) certification, which is a set of guidelines to assure a safe, effective finished product (<http://www.fda.gov/cdrh/comp/gmp.html>). Many of the tasks of the quality assurance subsystem are to control and assure the finished products' stance according to the obligatory guidelines.

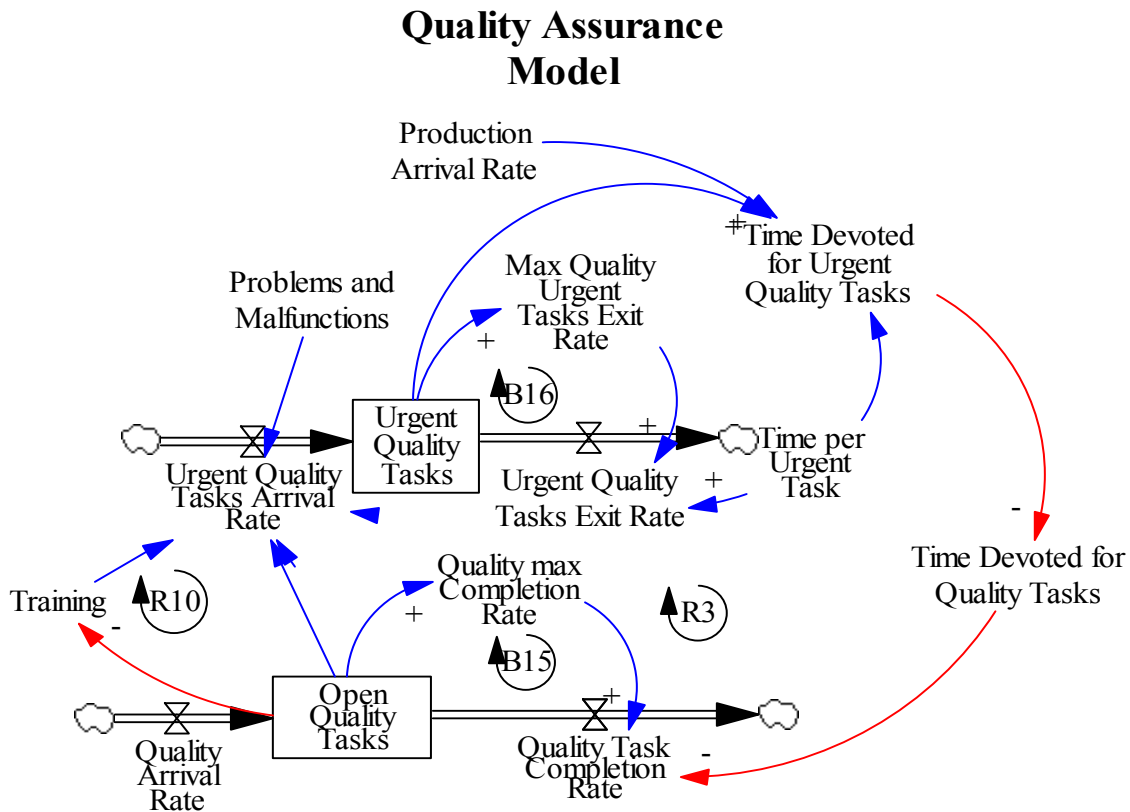


Figure 4-27: The Quality Assurance Stock and Flow Diagram

During the period of this research, the quality assurance department consisted of two workers whose main quality knowledge and practical training were acquired while working in the firm.

4.4.2.3.1 Stocks

Quality assurance model includes two stocks: *Open Quality Tasks* , which includes mainly the application of HACCP and GMP guidelines, and the *Urgent Tasks in Quality*, which is the result of the lack of workers' adherence to the quality and safety regulations during production.

4.4.2.3.2 Gathered Data and Initial Conditions

1. The quality arrival rate is between two and ten tasks per day uniformly distributed randomly.

2. The Quality Task Completion Rate depends on the time devoted to urgent tasks. If the time dedicated to urgent tasks is less than an hour on average, than the daily completion rate is between two and ten tasks uniformly distributed randomly; otherwise it will be less than that, depending on the number of urgent tasks occurring that day.
3. Time dedicated for urgent quality tasks depends on the number of urgent quality tasks and on the arrival rate of production tasks. All of these determine how much time needs to be dedicated to the urgent tasks in quality.
4. The average time for urgent tasks is between fifteen minutes and one hour, distributed according to a uniform random distribution.
5. The arrival rate of urgent tasks depends on the amount of problems and malfunctions in production and on the amount of open quality tasks. The open tasks in quality cause for more urgent tasks to occur which are distributed according to exponential distribution.
6. There is no quality culture. (See Section 2.2.3, p. 50) The workers who work in quality have many duties; consequently they are not free to invest time in improving the quality culture and training. The managers also do not invest time for these issues. Time devoted for training is mostly very rare.
7. The model code along with the equations for this subsystem is presented in Appendix K.

4.4.2.3.3 *Dynamic Hypotheses for Quality Assurance*

In order to ensure that no stocks will become negative, each stock is connected to a loop that examines the maximum allowable outflow rate (Sterman, 2000, p. 863). The real outflow rate is limited by the maximum rate. The loops that ensure that no stock will be negative are B15 and B16.

When the *Open Quality Tasks* increases, the *Urgent Quality Tasks Arrival Rate* increases too, causing the *Urgent Quality Tasks* stock to increase. The more *Urgent Quality Tasks* exist, more *Time Devoted for Quality Urgent Tasks* is needed, and therefore the *Time Devoted for Quality Tasks* decreases, which causes the *Quality Task Completion Rate* to decrease and the *Open Quality Tasks* to increase even more (loop R3).

When *Open Quality Tasks* increases, a lower percentage of them is for *Training* tasks, causing the *Urgent Quality Tasks Arrival Rate* to increase, and subsequently the *Urgent Quality Tasks* stock increases too. The more *Urgent Quality Tasks* increase, more *Time Devoted for Quality Urgent Tasks* is needed, and therefore the *Time Devoted for Quality Tasks* decreases, which causes for the *Quality Task Completion Rate* to decrease and the *Open Quality Tasks* to increase even more (loop R10).

4.4.2.3.4 Results

Open Quality Task:

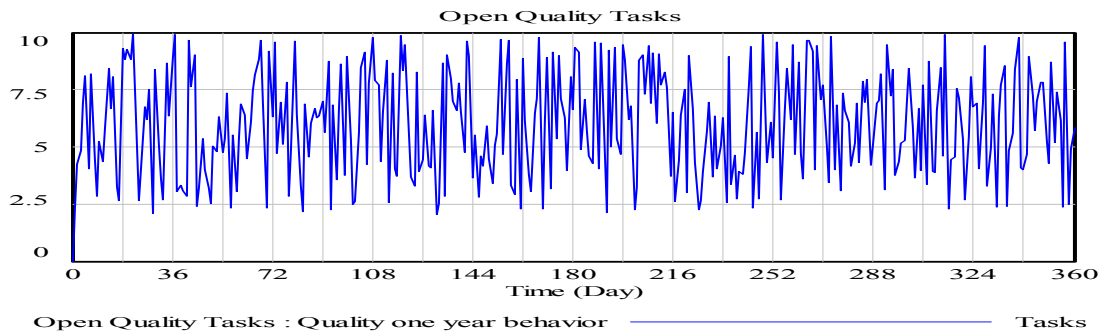


Figure 4-28: Open Quality Tasks Behavior over One Year

According to the data, the behavior of this stock is as it was anticipated: between two to ten daily.

Urgent Tasks in Quality:

Urgent Quality Tasks is usually not more than five to ten a day. In this model, it is between zero and five. The impact of other subsystems of the model like the production subsystem for instance, is still irrelevant.

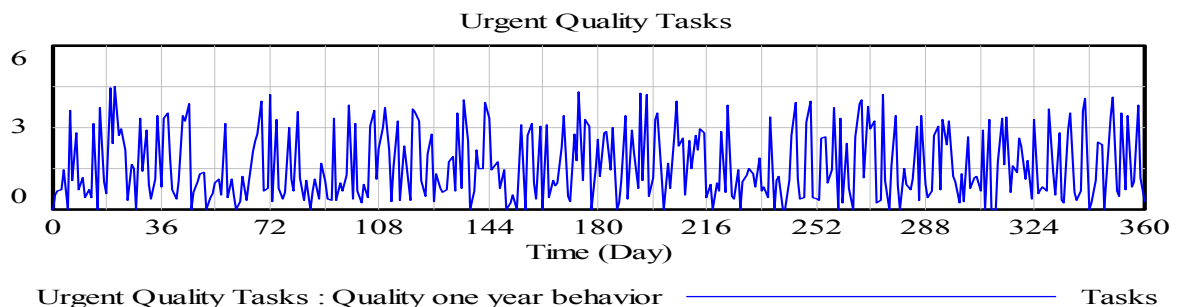


Figure 4-29: Urgent Quality Tasks Behavior over One Year

When more time is devoted to urgent tasks, less time is devoted to open quality tasks. The *Time Devoted for Quality Urgent Tasks* is provided in Figure 4-30.

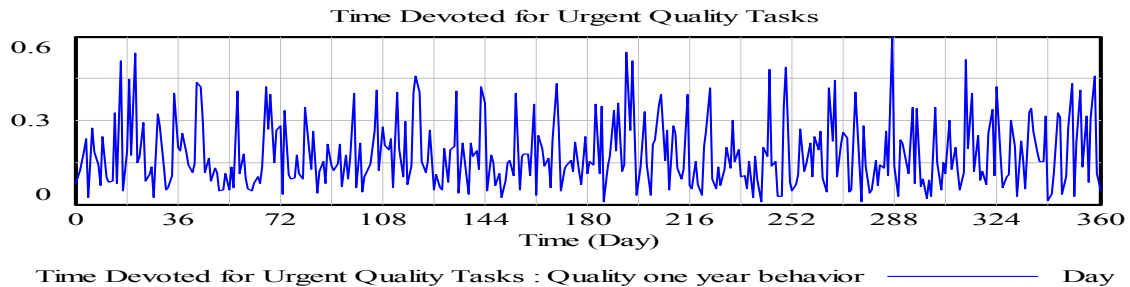


Figure 4-30: Time Devoted for Urgent Quality Tasks Behavior over One Year

According to Figure 4-30, the part of the day that is dedicated to urgent tasks in most cases is at least 0.02 (1.7 hours) and mostly 0.6 (5.2 hours). There are also days in which part time for urgent tasks rise above 0.6 (5.2 hours). This means that no much time is left for quality tasks, which reinforces the amount of urgent tasks. These results fit most of the daily occurrences observed in the firm.

4.4.2.4 The Inventory and Logistics Stock and Flow Model

The inventory and logistics department significantly determines the capability of performing regular work and managing the work processes efficiently. The inventory and logistics department deals with several kinds of activities that are very important and significant for the standard work processes. These include:

1. It is responsible for updating the quantity of the raw materials, which are in the inventory, in order to be able to take care of ordering the needed raw materials when required.
2. The department accepts the daily list of materials that are required for performing that day's tasks, and is responsible to gather the materials and provide them to the production.
3. The department is responsible to convey the finished products from the production to the inventory's warehouse. These products are divided into two categories: those that are designated for customers, and those that are designated to fill the finish goods inventory according to the management's policy.
4. The department serves the customers. Some of the orders are transported by trucks directly to the customers, while in other cases; the customers pick up their own orders.

From the above list of the inventory activities, the group members chose the tasks dealing with production needs and the direct tasks associated with the customers (activities two and four from the above list) as the most important tasks for the full model.

During the research period, two workers were performing the inventory's tasks, i.e., the manager and a permanent worker.

4.4.2.4.1 Stocks

This model contains two stocks: *Open Inventory Tasks for Production*, which is the stock of all the tasks that are necessary when providing the material production needs in order to finish its tasks. *Customers Waiting for Service* is the stock that deals directly with customers, usually with orders that have been completed and are waiting in the warehouse for them.

4.4.2.4.2 Parameters

Workers Time is one day of 8.67 hours.

4.4.2.4.3 Gathered Data and Initial Conditions

1. The production task arrival rate is between two and twelve per day uniformly randomly distributed.
2. The Production Time Resources are influenced by the Production Workers Pressure on Inventory for Immediate Service. The inventory Production Response Rate is distributed normally with means of 0.65 hours and standard deviation of 0.25.
3. The customers' arrival rate is between three and seven per day uniformly distributed.
4. The customers' exiting rate depends on the time resources dedicated for customers. The time resources are influenced by the customers' pressure for finished goods in inventory. The customers' exit rate is distributed normally with mean of 0.4 hours and standard deviation of 0.1.
5. The pressure exerted by production workers on inventory workers while pressing for rush service is a function of the pressure from to the amount of open tasks in inventory that is required for production tasks.

6. The pressure by customers on inventory workers while waiting for immediate service occurs when customers have to wait for their orders handled by inventory.
7. The level of interruptions stems from the two pressures, which are determined in inventory subsystem, i.e., the production pressure and the customers' pressure.
8. The model code and the associated equations for this subsystem are presented in Appendix K.

4.4.2.4.4 *Dynamic Hypotheses for Inventory and Logistics*

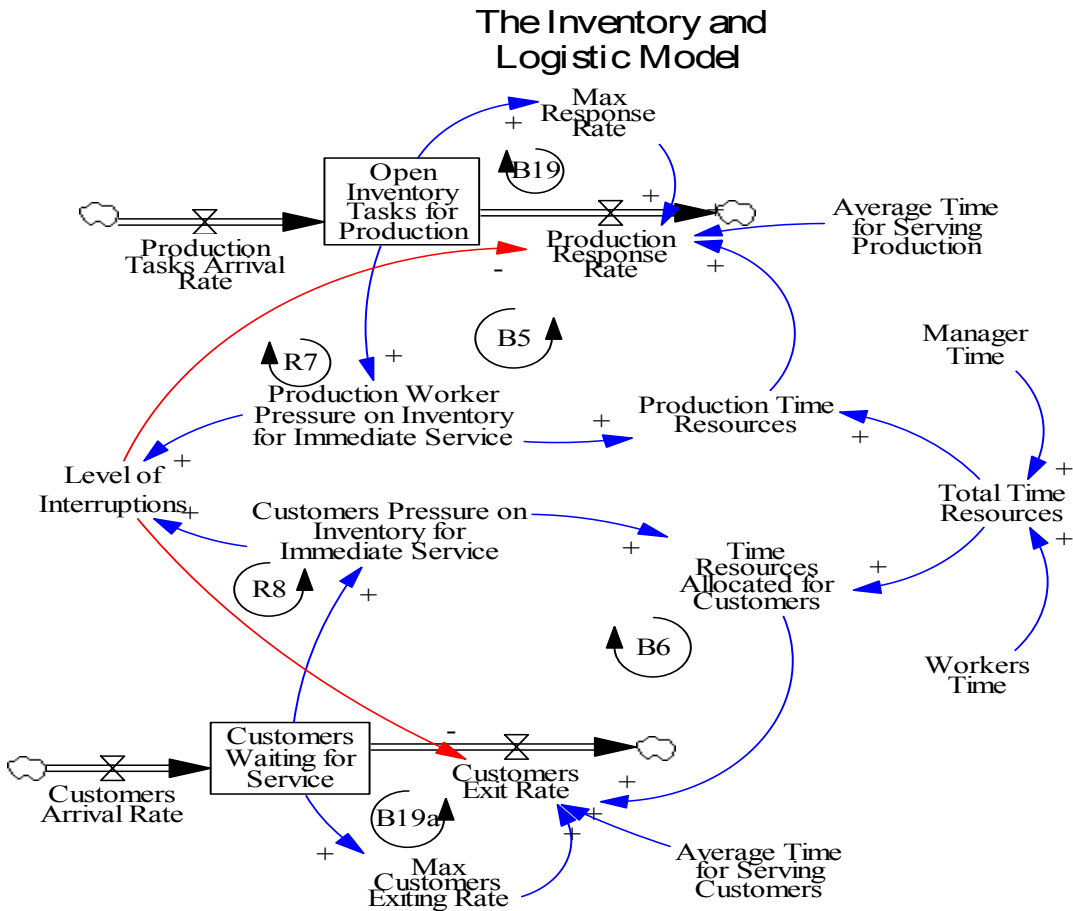


Figure 4-31: Inventory and Logistics Stock and Flow Diagram

In order to ensure that none of the stocks will be negative, each stock is connected to a loop that includes the maximum allowable outflow rate (Sterman, 2000, p. 863). The real outflow rate is limited by the maximum rate. The loops that ensure that the inventory will not be negative include B19 and B19a.

When the Production Tasks Arrival Rate increases, more Open Inventory Tasks for Production are waiting to be completed. This causes the Production Workers Pressure

on Inventory for Immediate Service to be higher, and also for the Production Time Resources to increase. Subsequently, the Production Response Rate increases thus, decreasing the Open Inventory Tasks for Production (loop B5). The relationship between the production pressure on inventory as a function of the open inventory tasks is shown in Figure 4-32.

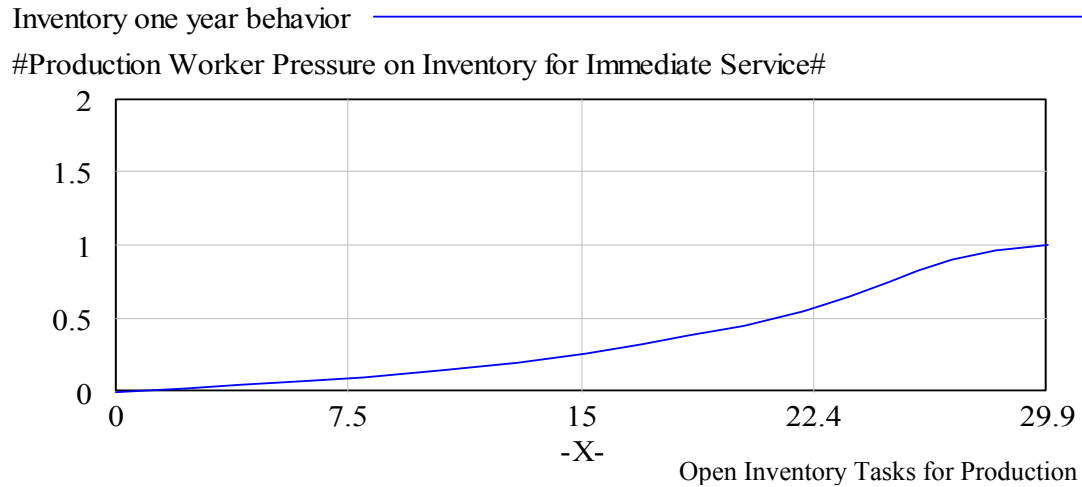


Figure 4-32: Production Worker Pressure on Inventory for Immediate Service as a Function of the Inventory Open Tasks

When the number of open production tasks increases, the pressure on inventory increases, but it grows sharply as the number of open tasks in production grows. After a certain number of open tasks, the pressure stays the same, because no additional pressure can influence the inventory anymore. Pressure cannot be more than 1, even when there are more tasks to produce (the pressure determines how many work hours (as percentage of the day) will be dedicated to these tasks).

When *Customers Arrival Rate* increases, there are more *Customers Waiting for Service*, and the *Customers Pressure by Inventory for Immediate Service* on inventory is higher, causing more *Time Resources Allocated for Customers* to increase. This increases the *Customers Exit Rate* (the service rate for customers), decreasing the number of *Customers Waiting for Service* (loop B6). Figure 4-33 describes the customers' pressure as a function of the number of customers waiting.

When the number of customers waiting for service increases, the pressure on inventory increases, but it grows sharply as the number of customers grows. After a certain number of waiting customers, the pressure stays the same, because no additional

pressure can influence the inventory any more. Pressure cannot be more than 1; even when there are more customers to service (the pressure determines how many work hours (as percentage of the day) will be dedicated to these customers).

Inventory one year behavior

#Customers Pressure on Inventory for Immediate Service#

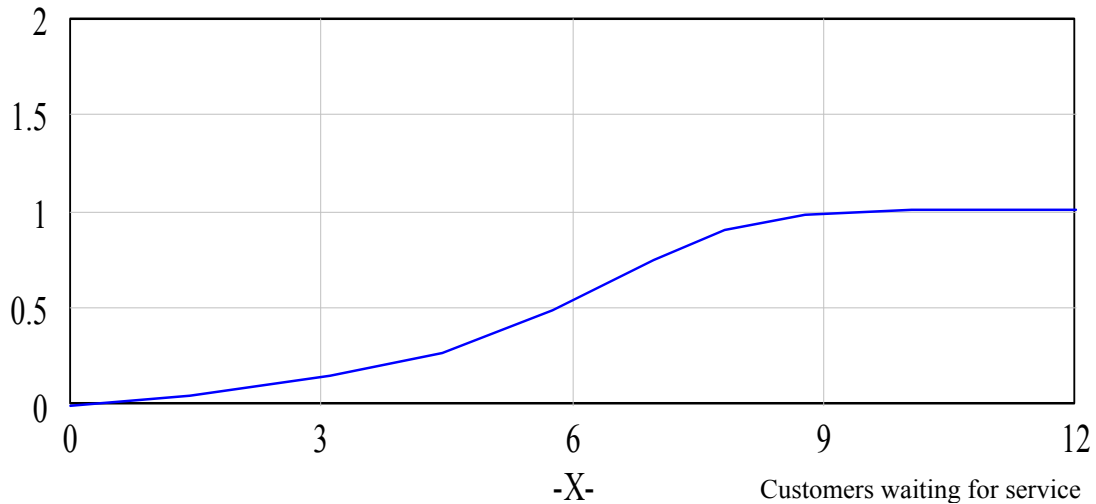


Figure 4-33: Customer Pressure on Inventory for Immediate Service as a Function of the Number of Customers Waiting

Production Workers Pressure on Inventory for Immediate Service influences the amount of *Level of Interruptions*. This decreases the *Response Rate for Production*, which increases the accumulation of *Open Inventory Tasks for Production*. When there are more *Open Inventory Tasks for Production*, the *Production Workers Pressure on Inventory for Immediate Service* increases, causing the *Level of Interruptions* to increase even more (loop R7).

The *Customer Pressure on Inventory for Immediate Service* increases the *Level of Interruptions* in the work. This decreases the *Customers Exit Rate*, which increases the number of *Customers Waiting for Service*. When there are more *Customers Waiting for Service* the *Customer Pressure on Inventory for Immediate Service* increases, causing the *Level of Interruptions* to increase even more (loop R8).

4.4.2.4.5 Results

Open Inventory Tasks for Production

According to the data, the production tasks arrival rate fluctuates between two and twelve tasks per day (See Section 4.4.2.4.3, p. 223), but the stock values are higher and attains values above fifteen tasks (Figure 4-34). According to the inventory managers such occasions happen, but rarely (he had no documents about it).

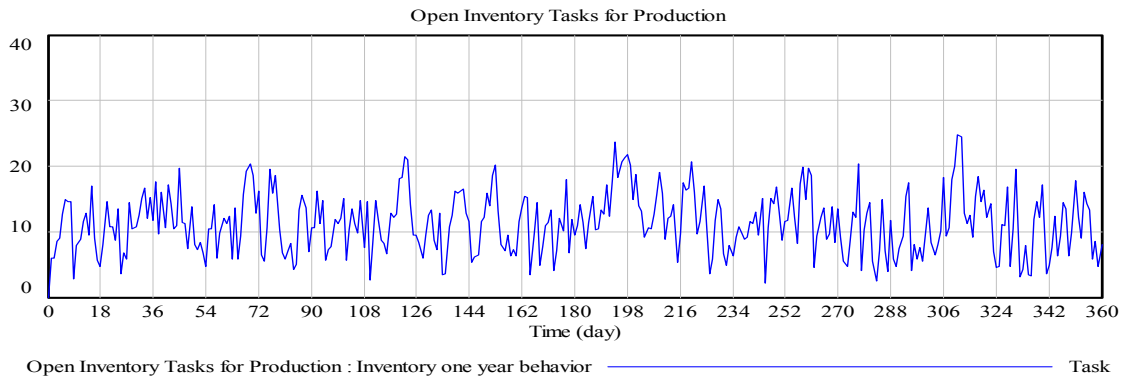


Figure 4-34: Open Inventory Tasks for Production Behavior over One year
Customers Waiting for Service

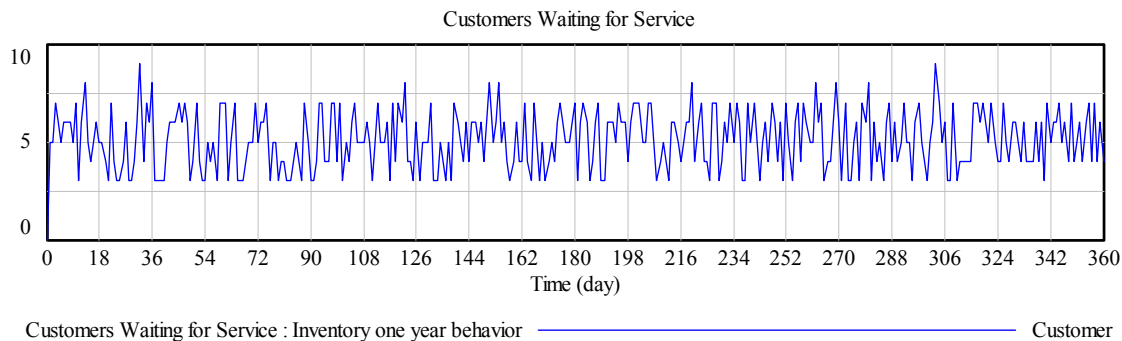


Figure 4-35: Customers Waiting for Service Behavior over One year

According to the data, customers’ arrival rate fluctuates between three and seven customers a day. According to the graph, some days the stock reaches eight customers waiting for service, which is very probable. Most of the days, it is between three customers and seven customers.

Level of Interruptions

The *Level of Interruptions* is an outcome of two pressures, as it is explained in Section 4.4.2.4.3 (p. 223). The results show us that *Customer Waiting Pressure* is always above zero and less than one. The *Production Workers Pressure on Inventory for Immediate Service* fluctuates between zero and one (the lowest and the highest levels).

This causes the *Level of Interruptions* to fluctuate between the value of zero and the value of one.

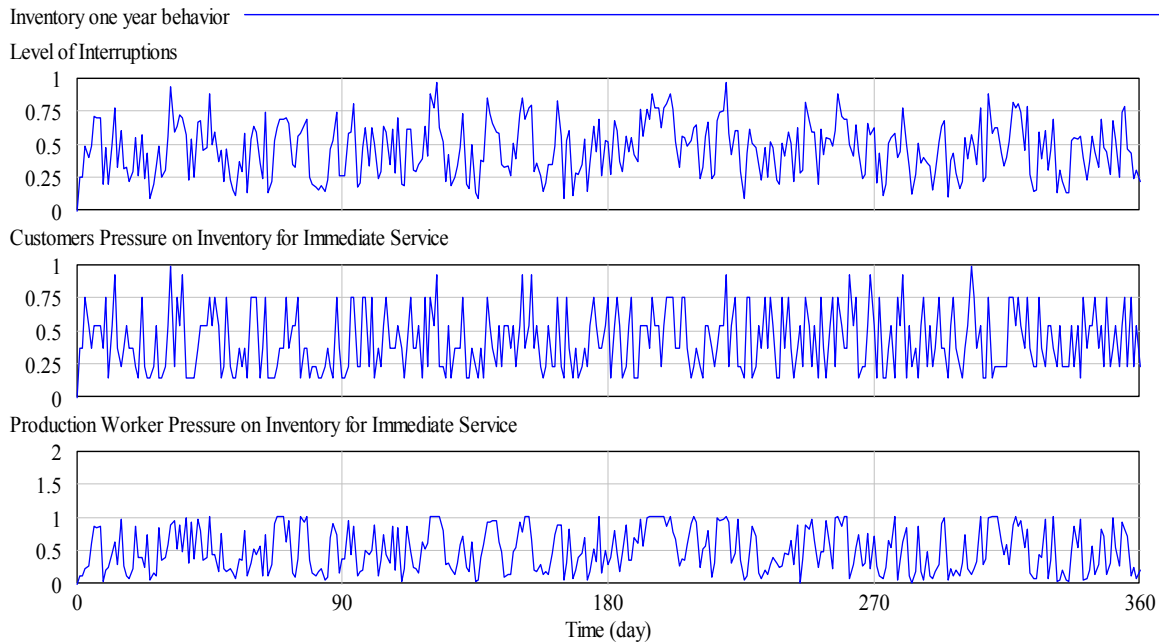


Figure 4-36: The Level of Interruptions Behavior over One Year

4.4.2.5 The Personal Stock and Flow Model

The personal subsystem is distinct in many aspects from all other subsystems. The personal subsystem is less tangible as it is a lot more difficult to quantify its variables accurately. Its real data and information are infrequent and are easy to be disputed, altered and modified. Different attitudes and approaches to the personal subsystem may result in different variables and different emphases on the data that are required to be collected.

For some variables in this subsystem it was possible to acquire information. However the variables related to the rate of absenteeism due to sickness and the variable related to overtime could not be quantified with certainty and confidence

The interest of this research is mainly to reveal the underlying interactions between workers health and quality culture in the firm. There are many aspects related to workers' health, but in this research the preference was to deal with personal stress in the workplace, an important issue of great concern in many studies dealing with workers' health (Rosen, 1995; Karasek and Theorell, 1990; Jaffe, 1995; Browne, 2000; Sapolsky,

1994; Reidel, et al. 2001; Ho, 1997; Homer, 1985). Stress is considered in literature as being very influential on both workers' health as well as on organizational effectiveness.

The group members had also considered stress as the main issue concerning their health. The group members raised several links to the personal stress notion, as described in Figure 4-10 (p.190). There is a linkage between workers' satisfaction in the workplace and their level of stress – the higher the satisfaction, the lower is the personal stress¹. Perceived Job Control is connected to personal stress – when the Perceived Job Control increases the personal stress decreases. The level of personal stress affects the frequency of sickness, the need to relax and the ability to experience and learn on the job. Satisfaction contributes to worker's motivation and commitment. Experience and learning influence quality culture positively. Most of these connections are also widely accepted in literature (Rosen, 1995; Karasek and Theorell, 1990; Jaffe, 1995).

The group members chose the variables they were interested in and related to their behavior as stocks (See Appendix G and Figure 4-12, p.202). These variables included personal stress, satisfaction level, commitment, Perceived Job Control and sickness. During the process of gathering information and formulating equations, Perceived Job Control and sickness remained influential variables instead of stocks, meaning that they were used as auxiliary variables.

Gathering the values for these stocks and auxiliary variables necessitated the use of questionnaires. The process of building and using questionnaires is explained in the following section. In chapter five, the use of questionnaire is reviewed and its reliability and validity are discussed.

4.4.2.5.1 Questionnaire

In order to measure all the involved variables in this subsystem, a questionnaire was developed based on several proven academic questionnaires in terms of validity and reliability.

Personal stress questions were taken from “The Global Inventory of Stress“, by Sheridan, L. Charles and Radmacher, R. Sally (1986). Job satisfaction questions were

¹ Personal stress: a physical or psychological stimulus that can produce mental tension or physiological reactions that may lead to illness

taken from “Job Satisfaction”, by Paul E. Spector (1997). Special questions were chosen to address the notion of satisfaction:

- Work Satisfaction
- Social Environment
- Opportunity for Promotion
- Monetary Compensation
- Managers Relations

This list was recommended by the group members as important variables for measuring satisfaction. (See Appendix G) Perceived Job Control questions were built according to “Healthy Work; Stress, Productivity, and the Reconstruction of Working Life”, by Robert Karasek and Tores Theorell (1990). Sickness information has been gathered from the firm’s administration office. Commitment questions have been taken from Cook, J. and Wall, T. (1980).

All questions are based on a five-point scale. A question is a phrase that describes a feeling or a thought. For most questions, the highest level of acceptance of the phrase is five while the lowest acceptance is one. For some questions the five-point was the lower acceptance level. This confusion is recommended for a reliable questionnaire. In order to be effective, the questionnaire was translated to Hebrew and simplified so that the production workers would be able to understand and answer the questions appropriately. Questionnaires were handed out to twenty four workers and seven managers. The results were obtained from twenty two workers and six managers. The questionnaires and the results are provided in Appendix M.

4.4.2.5.2 Stocks

The personal stock and flow diagram includes three stocks: *Employees Satisfaction Level*, *Personal Stress* and *Organization Commitment*.

4.4.2.5.3 Gathered Data and Initial Conditions

Most of the information of the personal subsystem was gathered using the questionnaire. Some of the variables in this model are impacted by some other variables. In order to quantify the values for each variable, weighting of the impact of each variable was done. The weights were determined using a questionnaire that was given to three employees. The questionnaire for weighting the variables happened to be a very

complicated process for the employees and took a lot of time for explanations. Therefore, only three managers were chosen to do it: one from quality, one from maintenance, one from production. They had to weight each variable according to their own individual perception. (See Appendix N) *Perceived Job Control* was considered as contributing to the *Experience and Learning Rate* and *Stress Relief Rate* only if this variable was above the average (2.5). If this variable was under the average, it was considered to contribute to the *Satisfaction Erosion Rate* and *Stress Accumulation Rate*.

1. *Experience and Learning Rate* is calculated by weighting *Work Satisfaction* (0.6), *Social Environment* (0.2), and *Perceived Job Control* (0.2) (only if this variable above the average, meaning that this variable is considered only if it has a mean value greater than 2.5).
2. *Satisfaction Erosion Rate* is calculated by weighting the following variables: *Overtime attrition* (0.05), *Monetary Compensation* (0.5), *Managers Relation* (0.05), and *Perceived Job Control* (0.2) (only if this variable is lower than the average, meaning, lower than 2.5).
3. *Stress Accumulation Rate* is calculated by weighting the following variables: *Managers Relations* (0.25), *Stress Level* (0.75), and *Perceived Job Control* (0.3) (only if this variable is lower than the average, meaning 2.5).
4. *Stress Relief Rate* is calculated by weighting the following variables: *Perceived Job Control* (0.4) (only if this variable above the average, meaning 2.5), *Personal Stress* multiplied number of *Sickness* days, and *Employees' Satisfaction Level* (0.2).
5. *Commitment Rate* is influenced by two variables: *Satisfaction*, and *Perceived Organizational Effectiveness*. When they increase, the *Commitment Rate* increases.
6. *Commitment Loss Rate* is also impacted by the extent of workers satisfaction. The lower the satisfaction; the higher the *Commitment Loss* is.

4.4.2.5.4 Dynamic Hypotheses for Personal

In order to ensure that no stocks will become negative, each stock is connected to a loop that includes the maximum allowable outflow rate (Sterman, 2000, p. 863). The real outflow rate is limited by the maximum rate. The loops that ensure that the stock values will be positive are B24 and B24a.

The higher the Personal Stress, the more Sickness occurs, which increases the Stress Relief Rate and lowers the Personal Stress (loop B23). The higher the Work Satisfaction, Social Environment, and Perceived Job Control, the higher is the Experience and Learning Rate, causing the Employees Satisfaction Level to increase, which results in an increase in the Stress Relief Rate, which is also influenced by Sickness. When Stress Relief Rate increases, Personal Stress decreases; this in turn decreases the Satisfaction Erosion Rate and increases the Employees Satisfaction Level even more (loop R5).

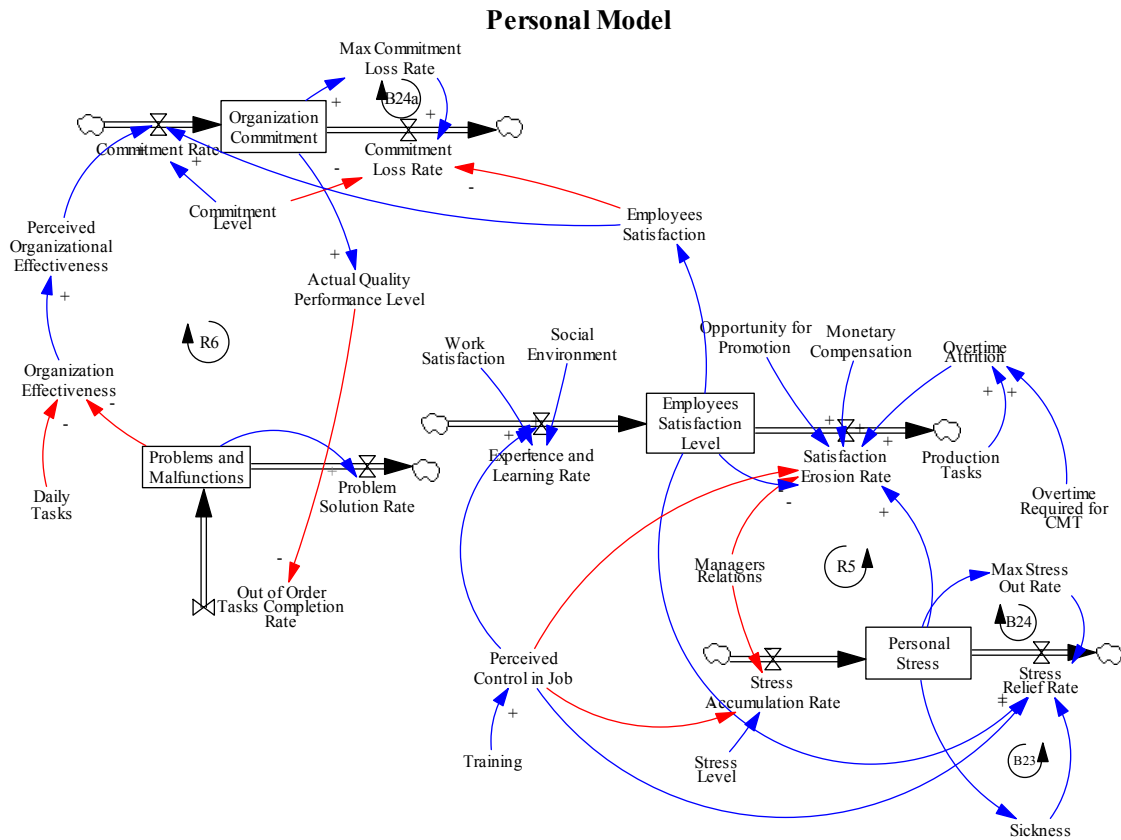


Figure 4-37: The Personal Stock and Flow Diagram

When *Problems and Malfunctions* increases, the *Organization Effectiveness* decreases, and so does the *Perceived Organizational Effectiveness*, which causes *Commitment Rate* to decrease, and *Organization Commitment* to decrease. When *Organization Commitment* decreases, *Actual Quality Performance Level* decreases, which increase the *Out of Order Tasks Completion Rate*, which causes the *Problems and Malfunctions* stock to increase even more (loop R6). Figure 4-38 presents the perceived

organizational effectiveness as a function of organizational effectiveness. It behaves exponentially.

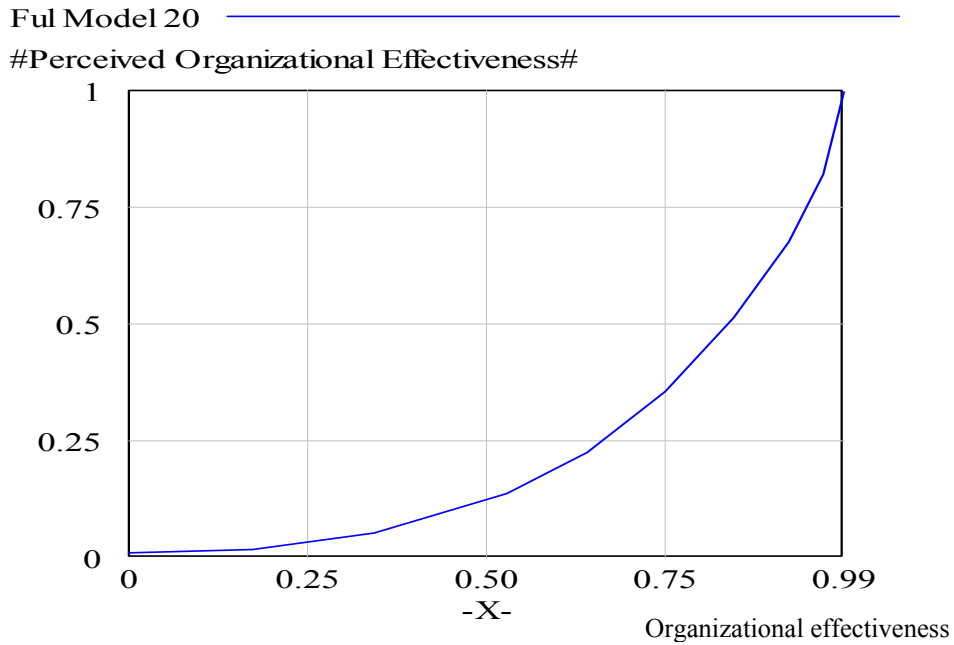


Figure 4-38: Perceived Organizational Effectiveness

Actual Quality Performance Level (Figure 4-39) is a factor of the level of commitment of employees. When the commitment is low, the *Actual Quality Performance Level* grows very gradually, but when the level of commitment is high, the *Actual Quality Performance Level*, grows faster.

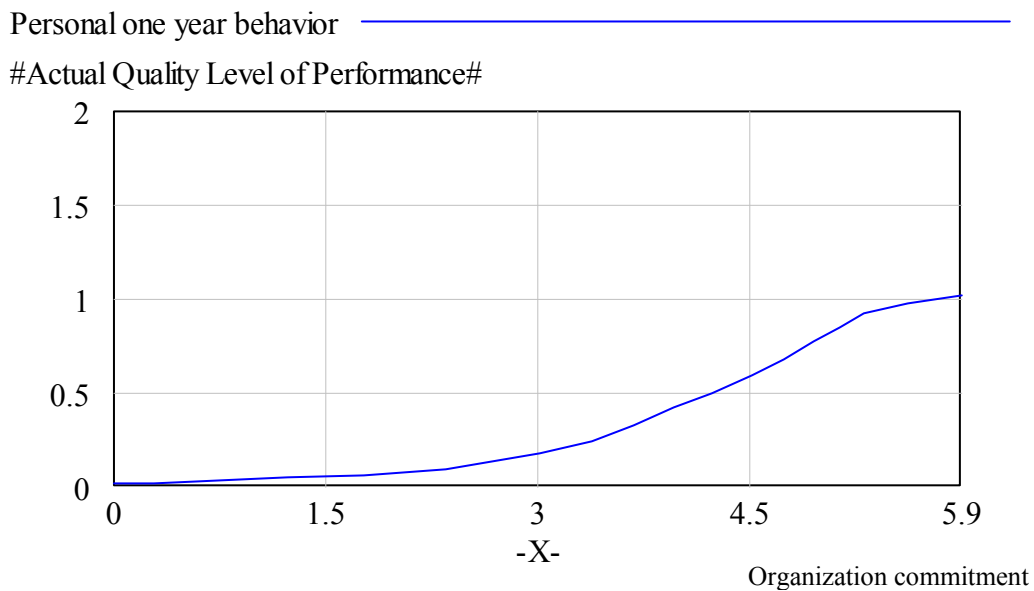


Figure 4-39: Actual Quality Performance Level

4.4.2.5.5 Results

Employees Satisfaction Level:

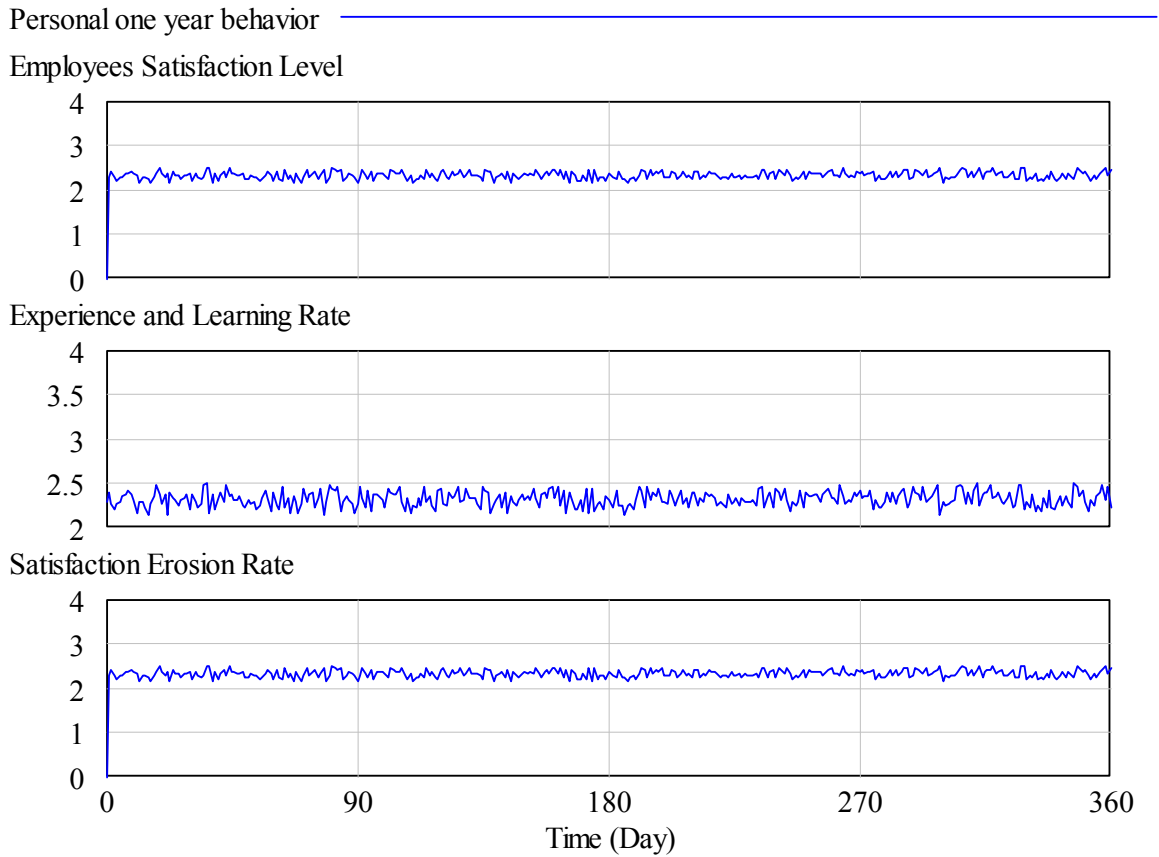


Figure 4-40: Employees Satisfaction Level Behavior over One Year

According to Figure 4-40, the *Experience and Learning Rate* does not exceed the average value of 2.5, which means a lower satisfaction than average. This rate does not change over time. The *Satisfaction Erosion Rate* is also under the average 2.5, which causes the stock, *Employees Satisfaction Level*, to run also under the average of 2.5, and has also with low variation. This means that according to the questionnaire, the *Employees Satisfaction Level* is stable in average.

Personal Stress:

Personal one year behavior

Personal Stress

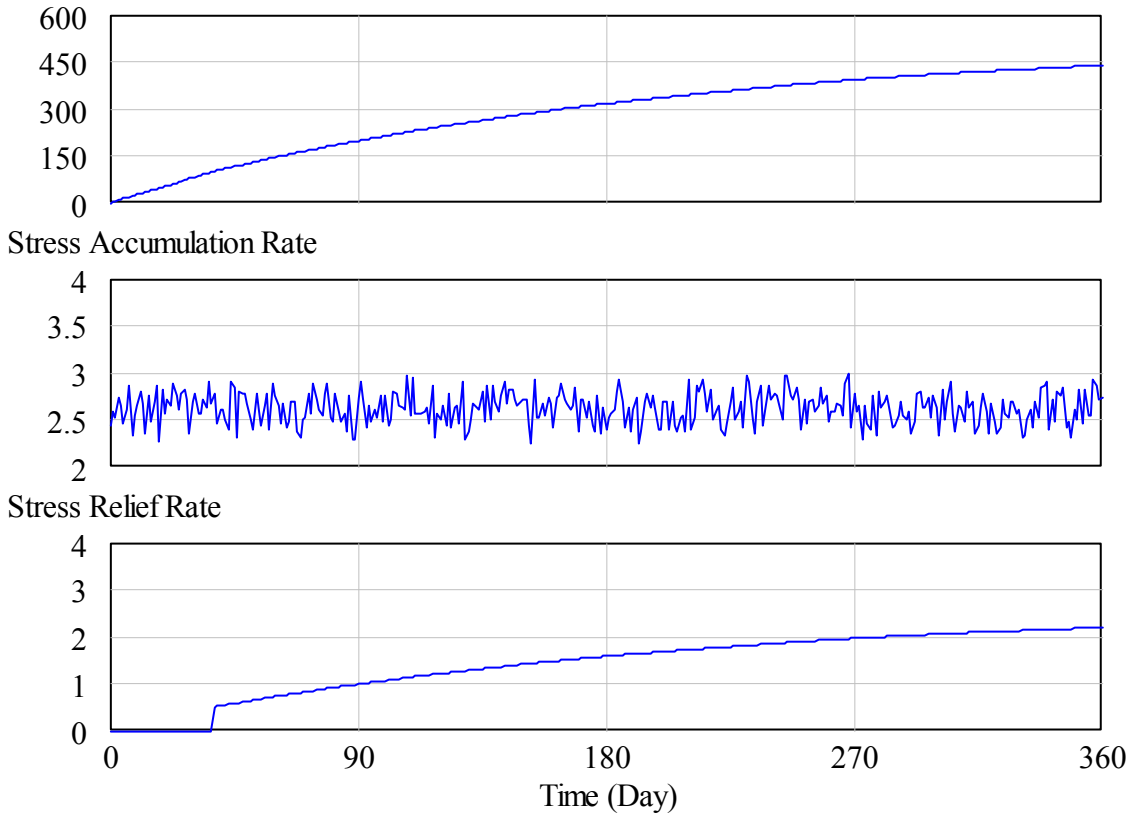


Figure 4-41: Personal Stress Behavior Over One Year

Stress Accumulation Rate is in many days above the average, meaning above two and a half. In the beginning of the simulation, the *Stress Releasing Rate* is zero for certain days and increases exponentially during the later days. The results of these inflow and outflow rate cause the *Personal Stress* to increase exponentially to a very high level. It reaches the level above 450 at the end of the year.

Organization Commitment:

Commitment Rate and *Commitment Loss Rate* are both influenced mostly by the *Employees Satisfaction Level*. The higher the *Employees Satisfaction Level* the higher is the *Commitment Rate* and the lower is *Commitment Loss Rate*, causing the *Organization Commitment* to increase. Since the behavior of the *Employees Satisfaction Level* is stable over this year (oscillating between 2.12 and 2.48), so is the behavior of the *Organization Commitment* is also stable (oscillating between zero and 0.4).

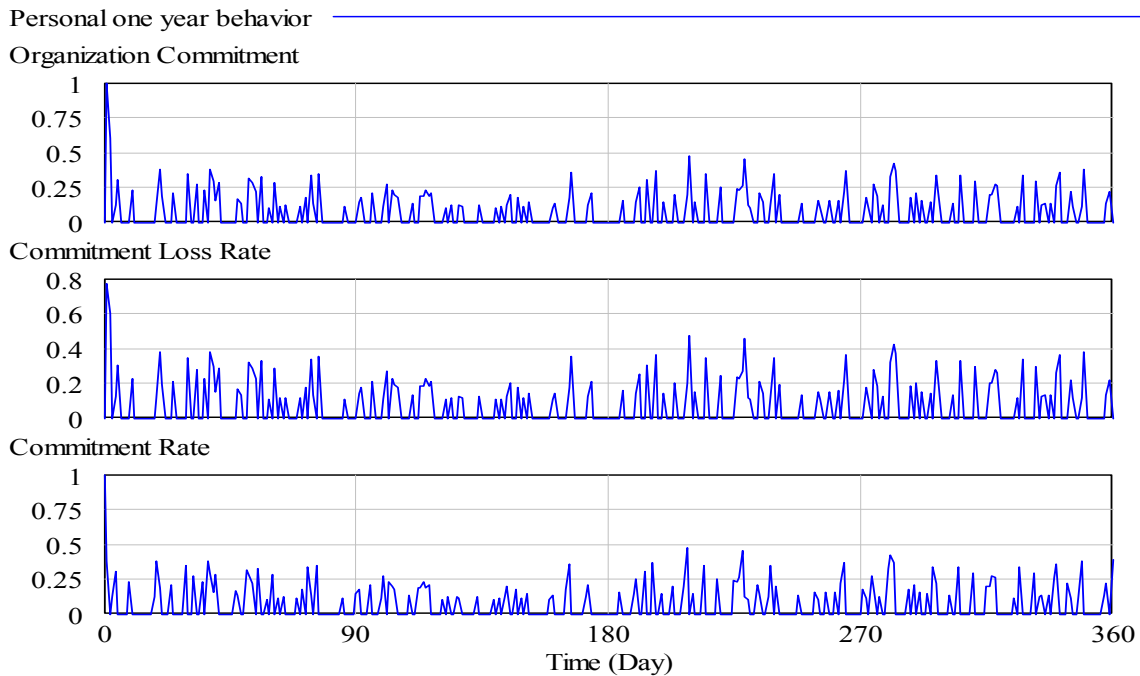


Figure 4-42: Organization Commitment Behavior Over One Year

4.4.2.6 The Stock and Flow Full Model

The process of building the full model is an iterative process. As explained in Section 4.4.2 (p. 203), in the beginning of the process, subsystem conceptual models were designed. Connecting all these subsystem models to one conceptual model was completed during the second phase. After the approval of this model by the group members, the third phase was selecting the variables that seem to be most important (Appendix F and G) for the understanding of the model behavior, and converting the conceptual model to a stock and flow diagram. (See Figure 4-12, p. 202) The next phase was an iterative process: going back to the subsystem conceptual models and converting them to quantitative models. Gathering information and data was done for each subsystem individually, and each subsystem's behavior was examined by comparing it to the real subsystem behavior. It is important to notice, that in real life, a subsystem is not independent from the other subsystems and therefore the behaviors of the subsystems are not always the same as those in the real world.

Connecting the different subsystems together to a full model was done naturally by using the first stock and flow diagram (Figure 4-12, p. 202) as the basis and modifications were accomplished according to the decisions, information and understanding of group participants and other workers.

As exhibited so far, the full model comprises five subsystems. Each subsystem contains causal loops that outline the relationships between the variables and also causal loops that are necessary for stocks to remain positive. Furthermore, the full model contains some new causal loops stemming from the relationship between subsystems. The relationship causal loops include the production and operation subsystem loops B3, B5a, R4 and R9 (Section 4.4.2.1, p. 203), the maintenance subsystem loops B8, B8a, B9, B10, B11, B12, B13 and B14 (Section 4.4.2.2, p. 208), the quality assurance subsystem loops R3 and R10 (Section 4.4.2.3, p. 218), the inventory and logistics subsystem loops B5, B6, R7 and R8 (Section 4.4.2.4, p. 222), and the personal subsystem loops B23, R5 and R6 (Section 4.4.2.5, p. 228). The following are the causal loops that are necessary for stocks to remain positive: the production and operation subsystem loops B1, B2, B2a, B21 and B22; for the maintenance subsystem loops B12, B17 and B18; for the quality assurance subsystem loops B15 and B16; for the inventory and logistics subsystem loops B19 and B19a, and for the personal subsystem loops B24 and B24a.

The new causal loops stemming from the relationship between subsystems, which are contained in the full model are the following: loops B5a and R4 provide the connection between the production and quality subsystem and loop R9 provides the connection between production and inventory subsystems. Furthermore, one stock is added to the overall model and this is *Quality Culture Level*. The formulation of the *Quality Culture Level* stock concept that included its rate equations was based on the Detert et al. (2000) and Hackman and Wageman (1995) studies.

Detert et al. (2000) suggest eight dimensions of quality culture and compare each one of them to the TQM philosophy. The first dimension refers to truth and rationality, which appears in the case of TQM according to Detert et al. as management by fact, one of the four change principles of TQM according to Hackman and Wageman (1995). The second dimension of quality culture is about the nature of time and the time horizon; adopting long-term planning and goal setting instead of focusing on the immediate business is a key to quality management interventions. In the TQM literature, one of the basic assumptions according to Hackman and Wageman is the preference long-term planning which is essential to long-term organizational survival. The third dimension deals with beliefs about what motivates humans. This issue suits the TQM assumption

about how people behave (Deming, 1986; Hackman and Wageman, 1995). The fourth dimension has to do with ideas concerning stability versus change, innovation, and growth. It is obvious that one of the main TQM change principles is learning and continuous improvement, since change is inevitable. The fifth dimension deals with the centrality of work in human life and the balance between work as a production activity and a social activity. According to Deteret et al. (2000), this issue is emphasized in TQM as the focus on work processes rather than on the results only. This is another change principle of TQM according to Hackman and Wageman (1995). The sixth dimension is about working alone or collaboratively. TQM explicitly advocates cooperation and collaboration and is one of the five TQM interventions according to Hackman and Wageman (1995). The seventh dimension is about the degree to which control is concentrated or shared. Quality culture advocates loosely controlled organization, where power and decisions are shared throughout the organization. This attitude is compatible with TQM intervention, which Hackman and Wageman term as “the use of process-management heuristics to enhance team effectiveness” (p. 314). The last dimension according to Detert et al. (2000) considers the nature of the relationship between an organization and its environment. It is about the importance an organization has for external constituents, like customers, competitors, and the environment. This is aligned with the TQM philosophy, which believes in customers’ partnerships and benchmarking. This is shown in Hackman and Wageman’s study as two of TQM interventions: measurement of customers’ requirements and creation of supplier partnerships.

Some of the important issues of TQM according to Hackman and Wageman, are not considered for quality culture as being explained by Detert et al. (2000). This includes two of the TQM assumptions, i.e., the responsibility of top management to total quality and the viewing of the organization as a system of highly interdependent parts. It also includes one change principle: the analysis of variability and one intervention. In other words, the use of scientific methods to monitor performance and to identify high leverage points for performance improvement, which advocates the use of statistical tools to monitor and analyze work processes.

In order to calculate the value of *Quality Culture Level* stock, four workers were asked to grade each of the previously mentioned dimensions between zero and one

(Appendix O). I also added the Quality Culture stock as expressed by Detert et al. (2000) and Hackman and Wageman (1995) to the model (Figure 4-43) and performed a simulation of the full model for one year. Each of the previously mentioned dimensions was considered equal to all the others in relation to its importance to Quality Culture.

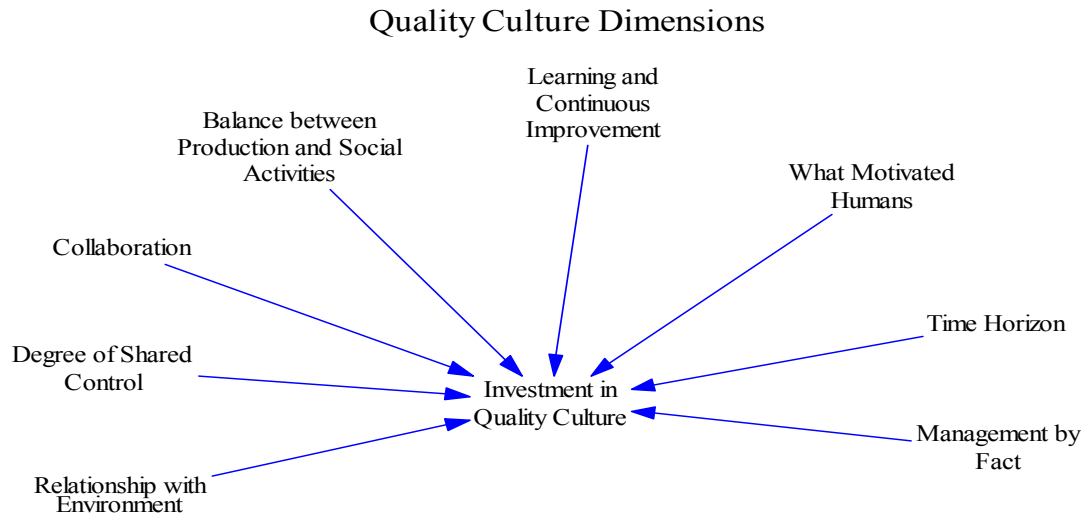


Figure 4-43: The Quality Culture Dimensions

The *Quality Culture Level* stock impacts the following according to the group participants: *Urgent Quality Tasks Arrival Rate*, *Correct Task Completion Rate*, *CMT Arrival Rate*, *Level of interruptions* and *Perceived Job Control*. Besides *Correct Task Completion Rate*, and *Perceived Job Control* there is an inverse relationship with all other variables: The higher the *Quality Culture Level* the lower the values of those variables.

New relationships are depicted with arrows from the *Production Tasks* stock and from the *Problem and Malfunctions* stock to the variable *Number of Required Machines*, which is connected to *Machines Startup Pressure* variable, and is a part of the maintenance subsystem. The values associated with the *Machines Startup Pressure* variable were a result of the difference between the number of machines that are available and the number of machines that are required. The *Number of Available Machines* determines the *Number of Unavailable Machines*, which determines the *Machine Gap* (the difference between the required and available machines). The *Problem and Malfunctions* stock is connected to the *Maintenance Problems Pressure*, which

influences the *Overtime Required for CMT (Corrective Maintenance Tasks)*. *Production Tasks Arrival Rate* in inventory is connected to the *Production Tasks*. *Production Tasks* is the major cause for the tasks arrival rate in inventory. *Pressure on Employees* in production influences the *Stress Level* of workers, which impacts the *Stress Accumulation Rate* in the personal subsystem. *Overtime Attrition*, a variable in the personal subsystem is affected by the *Production Tasks* stock and by the *Overtime Required for CMT* in maintenance. *Production Tasks* and the *Problem and Malfunctions* are the variables with which *Organization Effectiveness* is related and computed. *Level of Interruptions* in inventory decreases the *Possible Completion Rate* in production. *Sickness* in the personal subsystem decreases the *Correct Task Completion Rate* in production. *Training* in quality increases the *Possible Completion Rate* in production. It also increases the *Perceived Job Control* in the personal subsystem.

4.4.2.6.1 Dynamic hypotheses

As explained above, the new dynamic hypotheses, resulting from including all the subsystems into one model, are described subsequently. When the production arrival rate (*Orders Exit Rate*) increases, the *Time Devoted for Urgent Quality Tasks* increases resulting in the decrease of the *Possible Completion Rate*, and the decrease of the *Correct Task Completion Rate*. This in turn causes the *Production Tasks* stock to increase, and subsequently decreases the production arrival rate (*Orders Exit Rate*) (loop B5a).

When the stock of *Problems and Malfunctions* increases, the *Urgent Task in Quality Arrival Rate* increases resulting in the increase of the *Urgent Task in Quality*. Subsequently, this increases the *Time Devoted for Urgent Task in Quality* causing the *Possible Completion Rate* and the *Task Correctness Completion Rate* to decrease. When less production is completed through the *Task Correctness Completion Rate*, more production is completed by the *Out of Order Task Completion Rate*, causing the *Problems and Malfunctions* stock to increase even more (loop R4).

When the stock of *Production Tasks* increases, the *Production Task Arrival Rate* for inventory increases, causing the *Open Inventory Tasks for Production* to increase, and the *Possible Completion Rate* in production to decrease. Subsequently, the *Task Correctness Completion Rate* decreases causing the *Production Tasks* to increase even more (loop R9).

The Linkage between Quality Culture and Employees Health in the Field Organization (Full Model)

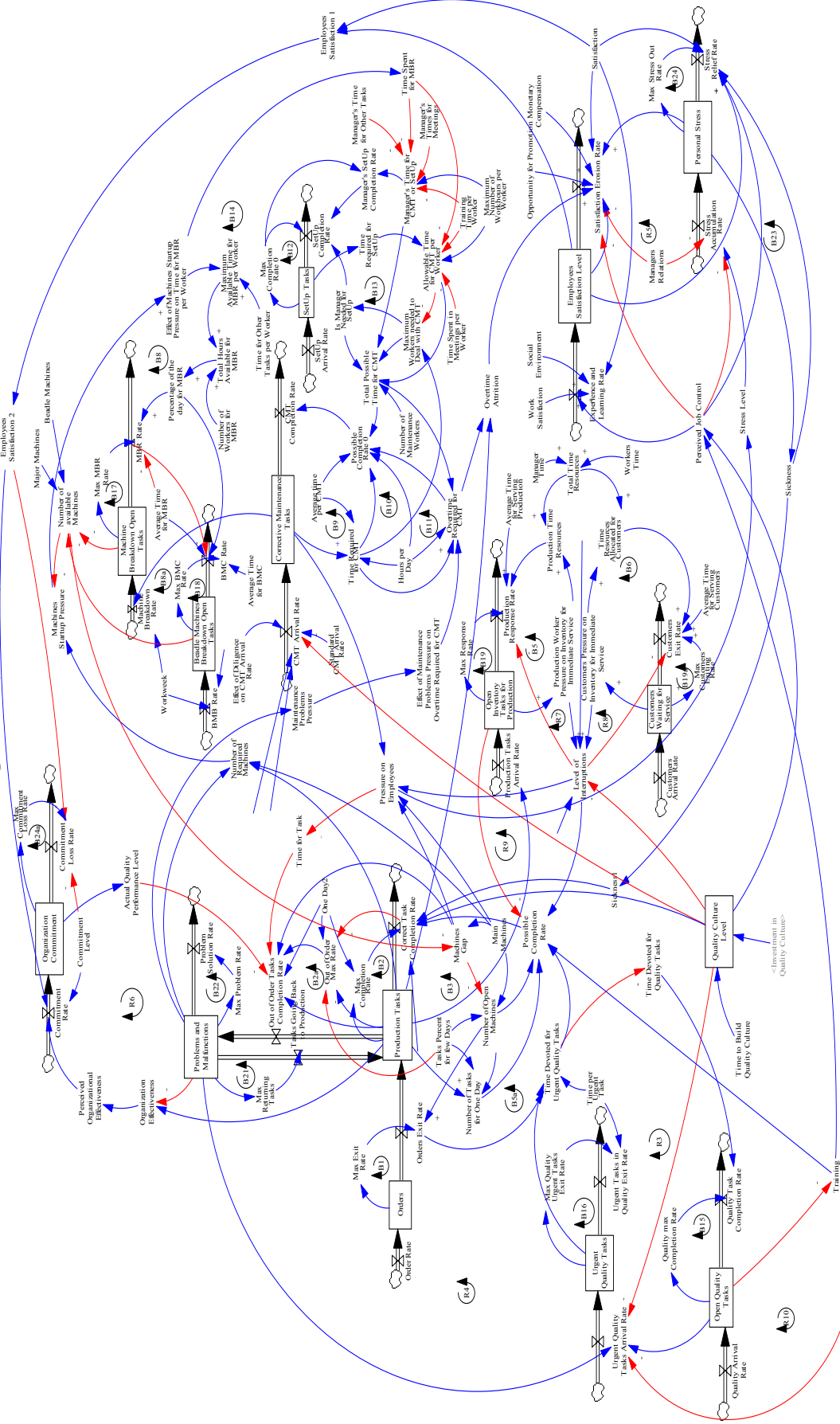


Figure 4-44: The Linkage between Quality Culture and Employees Health and Organizational Effectiveness in the Field Organization (Full Model)

4.4.2.6.2 Results

The results of the full model are introduced mostly by the graphs of the stocks with their inflows and outflows. Results of some of other variable are also introduced. The results of the model are compared with the results of the subsystems, in order to understand the behavior of the entire model.

Orders:

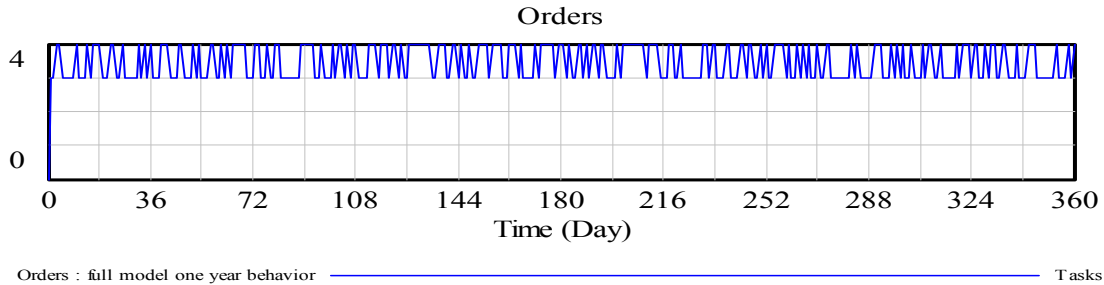


Figure 4-45: Orders Behavior Over One Year

The orders rate is between three and four orders per day, and the rate of orders entering production, depends on the number of open machines. The maximum major machines according to the data are seven machines which are not always available because some of them are used to correct tasks within *Problems and Malfunctions*. According to Figure 4-45, the *Orders* stock is between three and four. In the real system, there are sometimes more daily orders waiting for production (they were not included in the model because of their scarceness). Comparing these results with the production subsystem results (Section 4.4.2.1.5, p. 206) shows that the results are similar (Figure 4-15, p. 207).

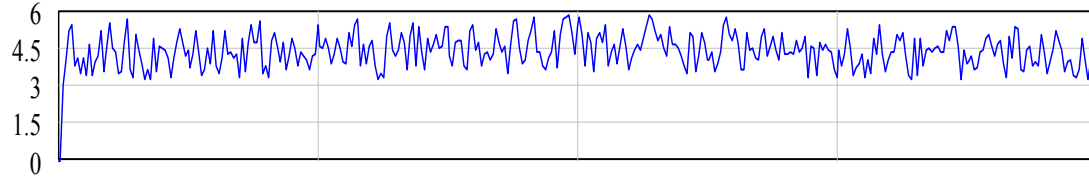
Production Tasks:

The *Production Tasks* stock oscillates between three and six tasks similar to the behavior in the production subsystem (Figure 4-14, p. 207). The *Correct Task Completion Rate* is less than five tasks per day for most of the days (normally, between one and a half and four tasks per day), while the *Out of Order Tasks Completion Rate* is lower and oscillates between zero and two tasks per day. Comparing these results to the subsystem results shows a worsening of the situation (Figure 4-14, p. 207). This is caused by two variables: the *Machine Gap*, the gap between the required machines and the available machines, and the *Pressure on Employees*, which in the full model is impacted

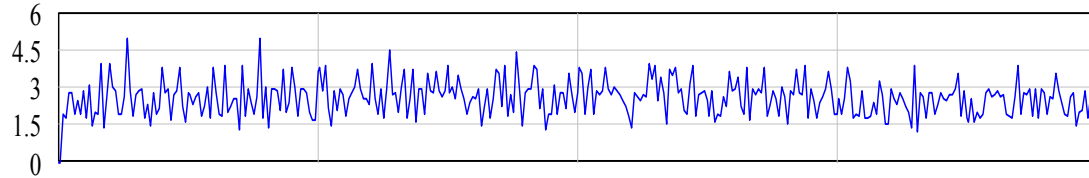
by from more variables including: *Corrective Maintenance Tasks* and *Level of Interruptions* in inventory.

full model one year behavior2

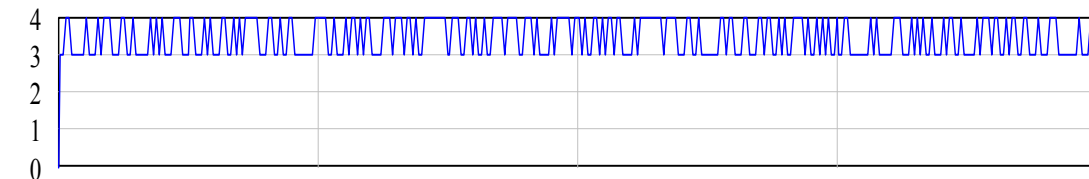
Production Tasks



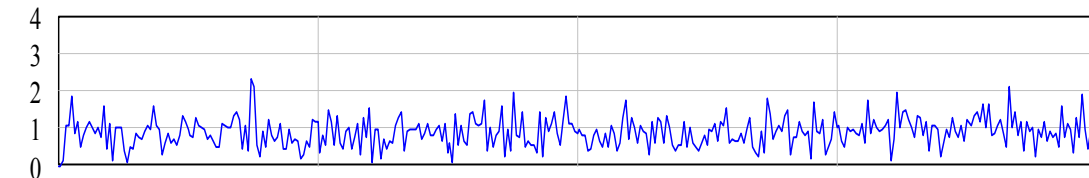
Correct Task Completion Rate



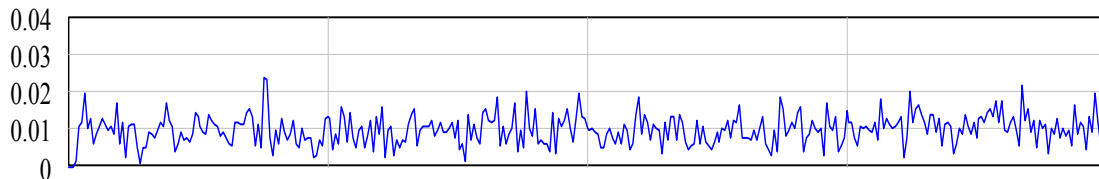
Orders Exit Rate



Out of Order Tasks Completion Rate



Tasks Going Back to Production



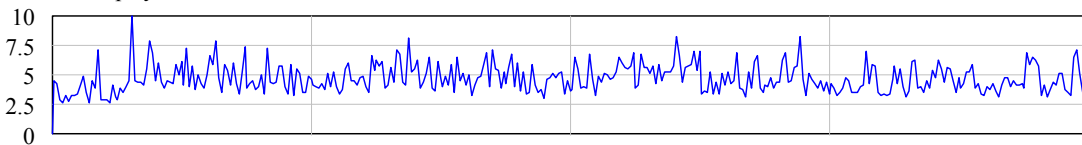
0 90 180 270 360
Time (Day)

Figure 4-46: Production Tasks Stock Behavior over One Year

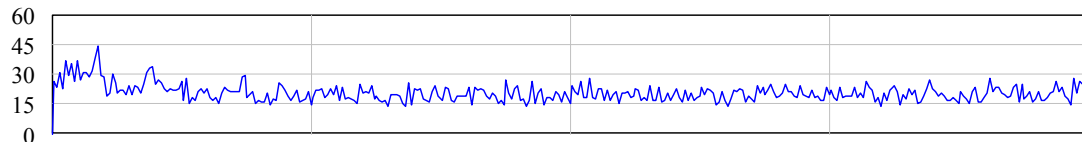
Pressure on Employees:

full model one year behavior2

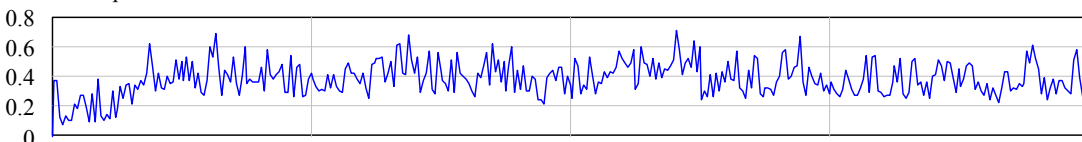
Pressure on Employees



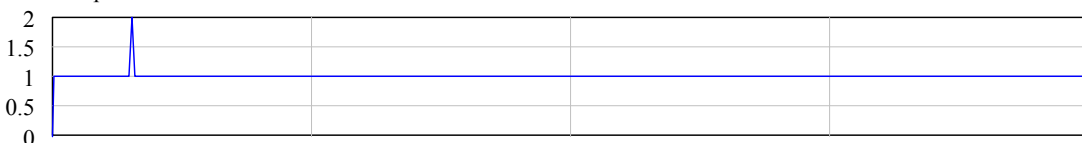
Corrective Maintenance Tasks



Level of Interruptions



Machines Gap



Time (Day)

Main Machines

full model one year behavior2: 7

Task0

full model one year behavior2: 1

Figure 4-47: Pressure on Employees Behavior over One Year

Pressure on Employees oscillates as a result of the relationship with other variables that affect the *Pressure on Employees*, especially the *Corrective Maintenance Tasks* and the *Level of Interruptions*, which belong to other subsystems. The connection between the subsystems increases the oscillation of *Pressure on Employees* and decreases *Correct Task Completion Rate*. This dependency is experienced in the real system.

Problems and Malfunctions:

Problems and Malfunctions stock oscillates between 0.2 and two and a half tasks. As mentioned previously in relation to Figure 4-46, all the results of the *Problems and Malfunctions* stock and the rates it relies on, oscillate with larger amplitude in the full model than the corresponding results in the production subsystem because of the additional feedback loops.

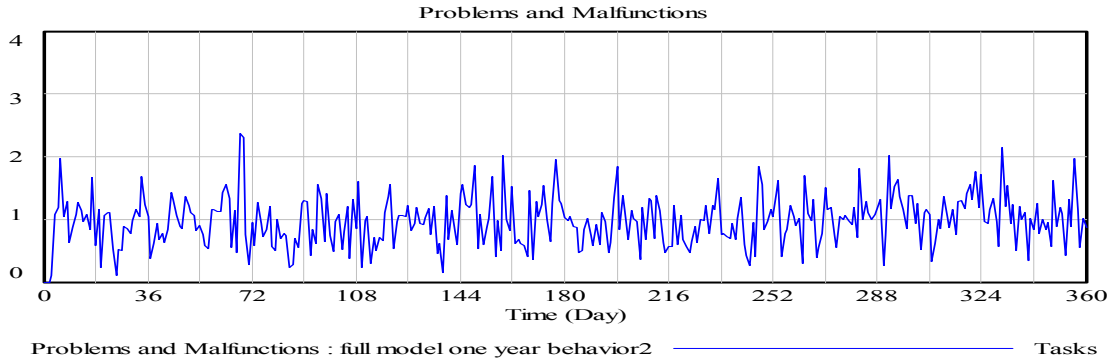


Figure 4-48: Problems and Malfunctions Behavior over One Year

SetUp Tasks:

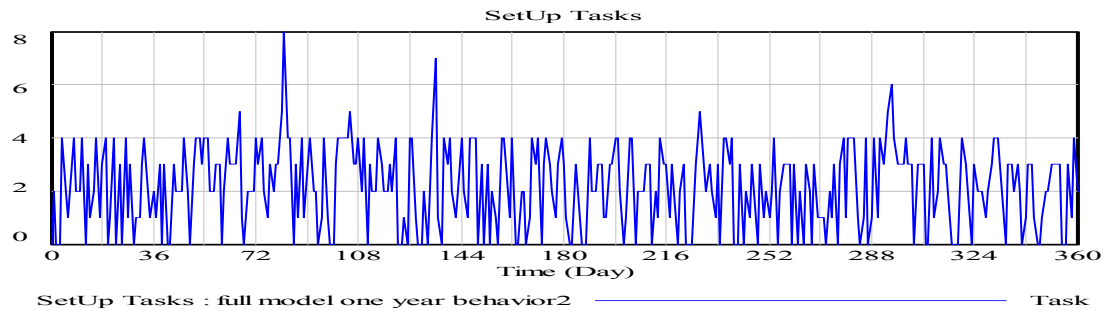


Figure 4-49: SetUp Tasks Behavior over One Year

Most of the days, *SetUp Tasks* are below six tasks. On some days they increase to eight tasks. The results of *SetUp Tasks* in the maintenance subsystem are similar (Figure 4-24, p. 217). In the real system, this variable oscillates between zero and five for most of the days (there is no written documentation about this behavior. This is based on input from the maintenance manager).

Corrective Maintenance Tasks:

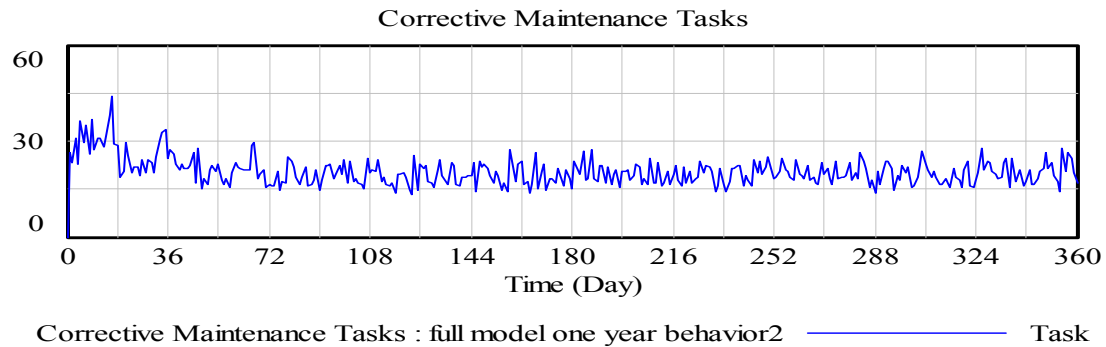


Figure 4-50: Corrective Maintenance Tasks Behavior over One Year

The *Corrective Maintenance Tasks* oscillates between fifteen tasks and thirty tasks per day in most cases. These results of the *Corrective Maintenance Tasks* stock in the full model and the results in the maintenance subsystem (Figure 4-23, p. 217) on average are alike but in the subsystem some results are higher results (above forty tasks). I assume that *Quality Culture Level* reduces the increase of the *Corrective Maintenance Tasks*. In the real system according to the maintenance manager (See Section 4.4.2.2.3, p. 210), the *Corrective Maintenance Tasks* oscillates between twenty tasks and thirty two tasks per day in most cases, which fits what is described in Figure 4-50.

Machine Breakdown Open Tasks:

The *Machine Breakdown Open Tasks* stock (Figure 4-51) is usually less than one machine per day. According to the maintenance information, the rate is between zero and two per day. These are same results as in the subsystem of maintenance (Figure 4-25, p. 218). On average, the results confirm to the real system's behavior.

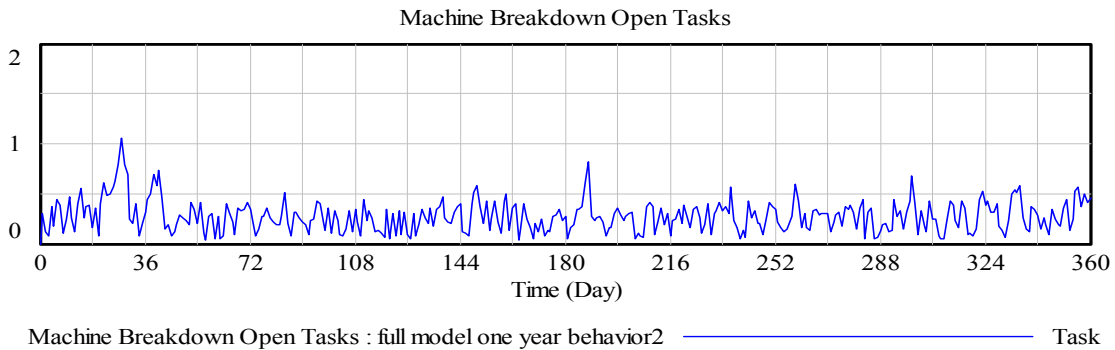


Figure 4-51: Machine Breakdown Open Tasks Behavior over One Year

Beadle Machines Breakdown Open Tasks:

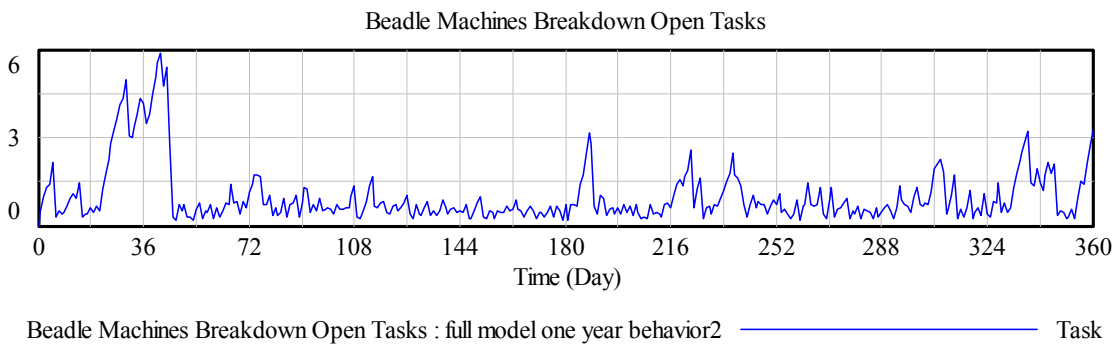


Figure 4-52: Beadle Machines Breakdown Open Tasks Behavior over One Year

Beadle Machines Breakdown Open Tasks is fewer than four machines that breakdown per day in most of the days. This is consistent with the subsystem results (Figure 4-26, p. 218) and the real system behavior.

Open Quality Tasks:

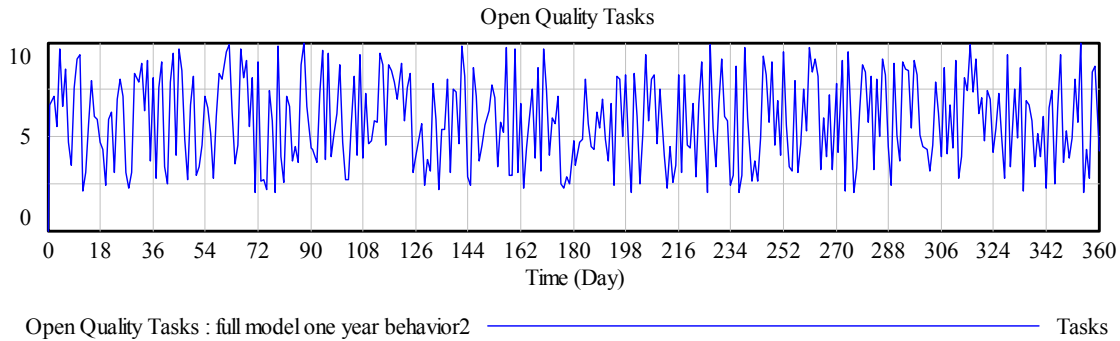


Figure 4-53: Open Quality Tasks Behavior over One Year

The behavior of the *Open Quality Tasks* in the full model is identical to its behavior in the quality subsystem. It runs between two and ten tasks per day (Figure 4-53). This is consistent with the gathered data (Section 4.4.2.3.2, p. 219).

Urgent Tasks in Quality:

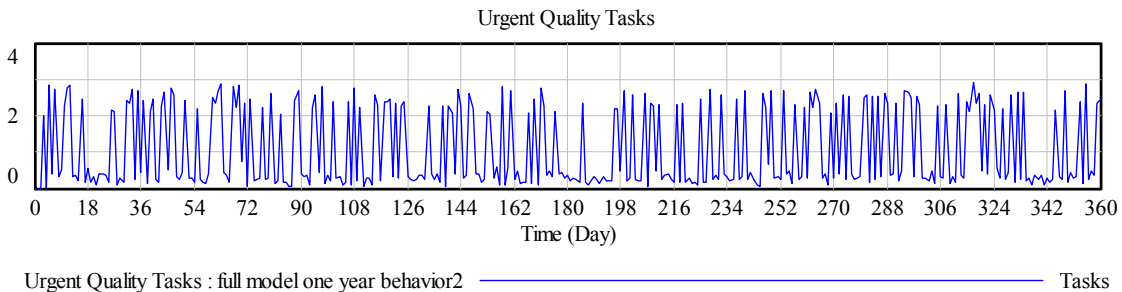


Figure 4-54: Urgent Quality Tasks Behavior over One Year

The number of the *Urgent Quality Tasks* in the full model is less than four, which is less than expected considering the behavior of this stock in the quality subsystem. (Figure 4-29, p. 221) I assume that *Quality Culture Level* reduces the values of this variable. There were no documents in the firm that could provide information about its behavior in the real system. According to the quality workers, this variable oscillates sometimes above five tasks per day.

Time Devoted for Urgent Tasks in Quality:

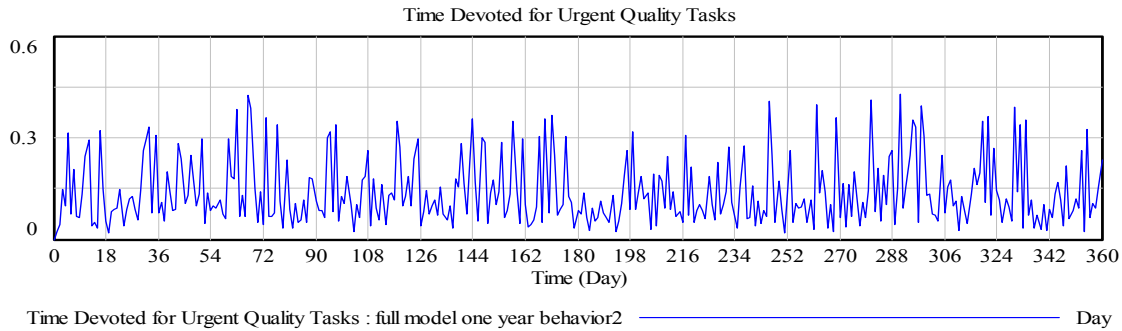


Figure 4-55: Time Devoted for Urgent Quality Tasks Behavior over One Year

The results of the full model are almost the same as the results of the quality subsystem model. (Figure 4-30, p. 222) Devoting 0.3 - 0.45 of the day for urgent quality tasks, means that 2.6 – 3.9 hours cannot be devoted to open quality tasks. In the case of the quality subsystem, there are also days in which part time for urgent tasks rise above 0.6 days (5.2 hours). Since *Time Devoted for Urgent Quality Tasks* is impacted by the *Urgent Quality Tasks* which is impacted by *Quality Culture Level*, I assume that *Quality Culture Level* reduces the values of this variable. There are many reasons for the existence of quality urgent tasks as workers argue: lack of training, pressure to finish tasks sooner, the use of many temporary employees, etc.

Quality Culture Level:

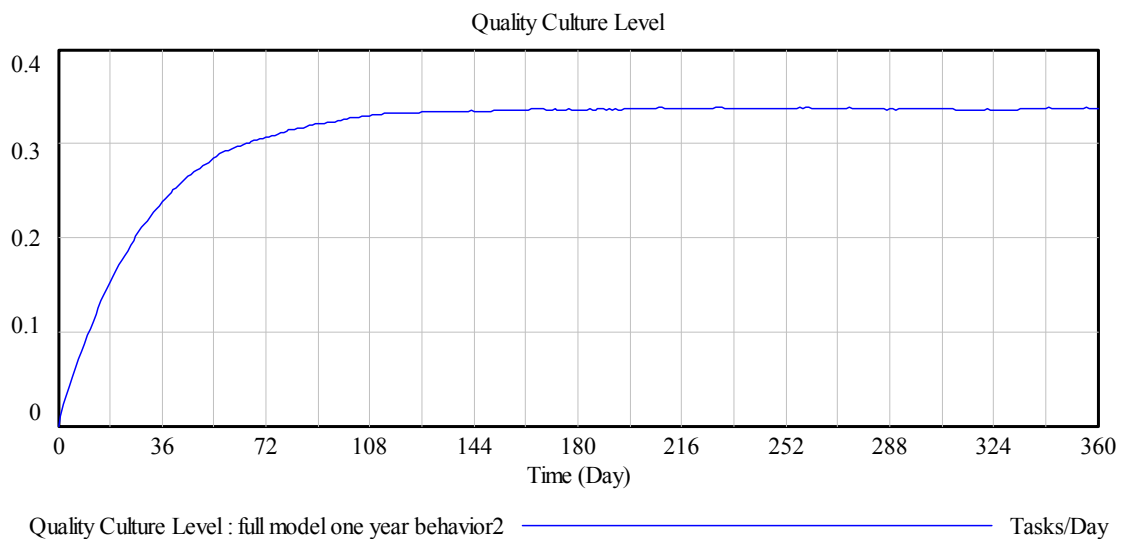


Figure 4-56: Quality Culture Level Behavior over One Year

The method I used to measure *Quality Culture Level* is explained in Section 4.4.2.6 (p. 236). Measuring quality culture is a difficult task especially trying to do this

accurately. I used Detert et al. (2000) and Hackman and Wageman (1995) studies in order to measure the quality culture of the firm. The results of the interviews I completed with four workers (Appendix O) provided the behavior of quality culture as depicted in Figure 4-56. The workers were required to grade the dimensions of the quality culture between zero and one. Therefore the result that was obtained presented the level of quality culture that characterizes the organization. According to the workers, *Quality Culture Level* beneath 0.4, is still not an adequate level of culture for the workplace.

Open Inventory Tasks for Production

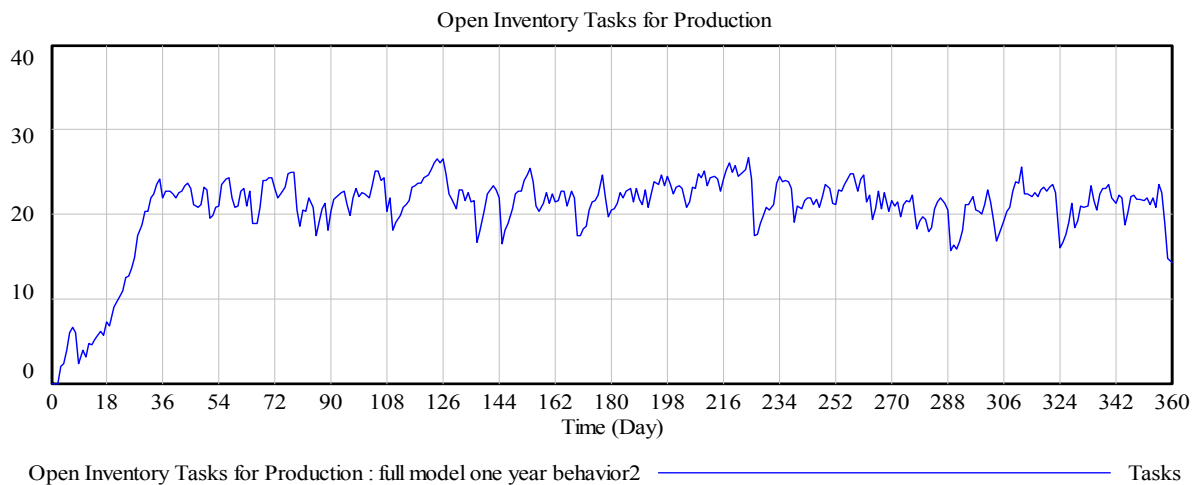


Figure 4-57: Open Inventory Tasks for Production Behavior over One Year

Open Inventory Tasks for Production oscillates between fifteen and almost twenty eight tasks. The behavior is cyclical. In most cases, the open tasks are less than twenty five, a little higher than the subsystem's results. The *Open Inventory Tasks for Production* is connected to feedback loop R9 - a new feedback loop in the full model. According to this causal loop, *Open Inventory Tasks for Production* impacts the *Possible Completion Rate* in Production, which impacts the *Production Tasks* stock. Subsequently, the *Production Tasks* stock impacts back the inflow of the *Open Inventory Tasks for Production*. It is also impacted by the *Quality Culture Level* through the *Level of Interruptions*. The behavior of *Open Inventory Tasks for Production* was accepted by the inventory manager who presented the above explanations as to the reasons that cause the specific behavior.

Customers Waiting for Service

Customers Waiting for Service runs between three and seven customers (Figure 4-58) during most of the days. In some days it is above seven. The results are mostly similar to those of the inventory subsystem (Figure 4-35, p. 227).

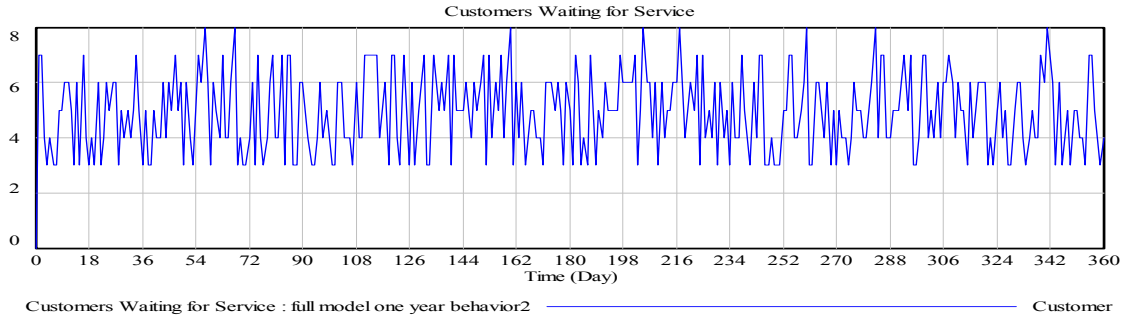


Figure 4-58: Customers Waiting for Service Behavior over One Year

Level of Interruptions

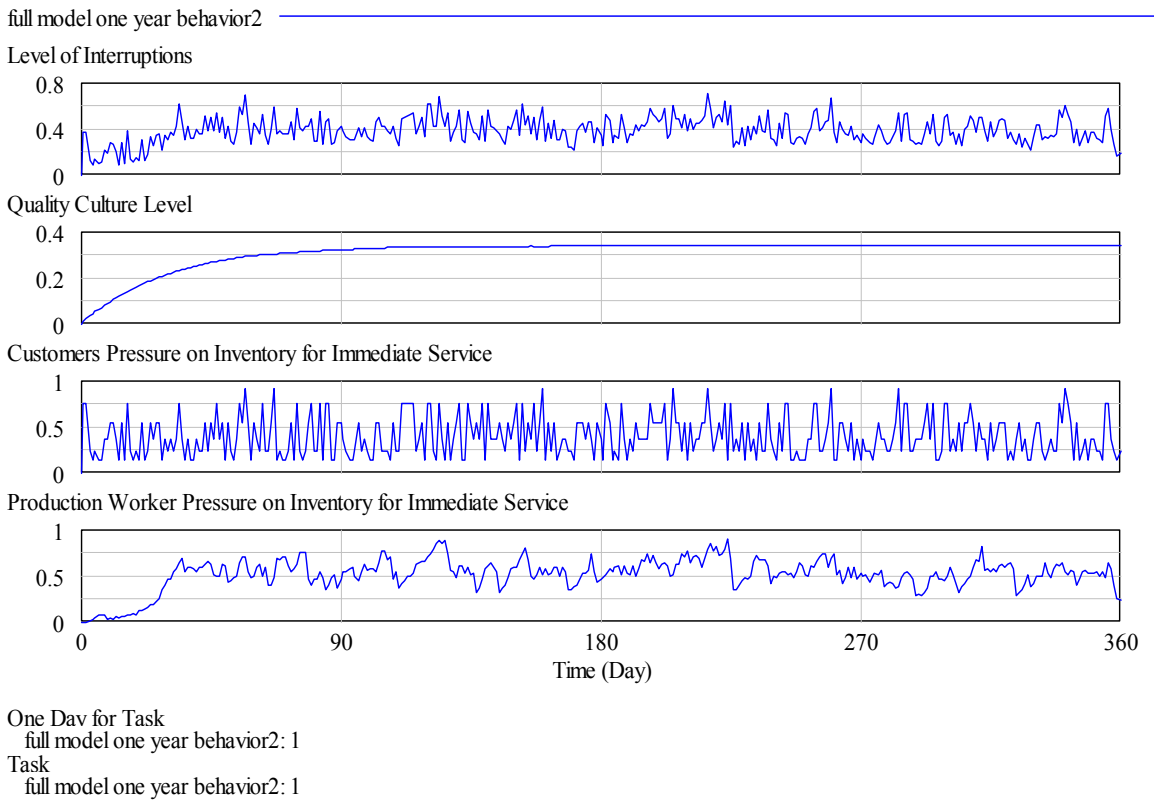


Figure 4-59: Level of Interruptions Behavior over One Year

The *Level of Interruptions* is influenced by three variables: Positively by the *Customer Pressure on Inventory for Immediate Service*, which runs between zero and one as its maximum, positively by the *Production Workers Pressure on Inventory for Immediate Service*, which runs between zero and one, and inversely if it is above 0.4, by

the *Quality Culture Level* stock (which in this model is under 0.4). The results of the *Level of Interruptions* are mostly between 0.1 and 0.7, which represent the percent of interruptions per day from the total number of tasks (Figure 4-59). The results in the inventory subsystem are mostly between 0.2 and 0.9 with more fluctuation. I assume that the *Quality Culture Level* decreases the values of this variable.

Employees Satisfaction Level

The results in this stock (Figure 4-60) are the same as the results in the personal subsystem (Figure 4-40, p. 234). The inflow and the outflow rate for this stock are a function of the results of the questionnaire and are not influenced by the relations of this model. Therefore, the results of this model are the same as those in the personal subsystem.

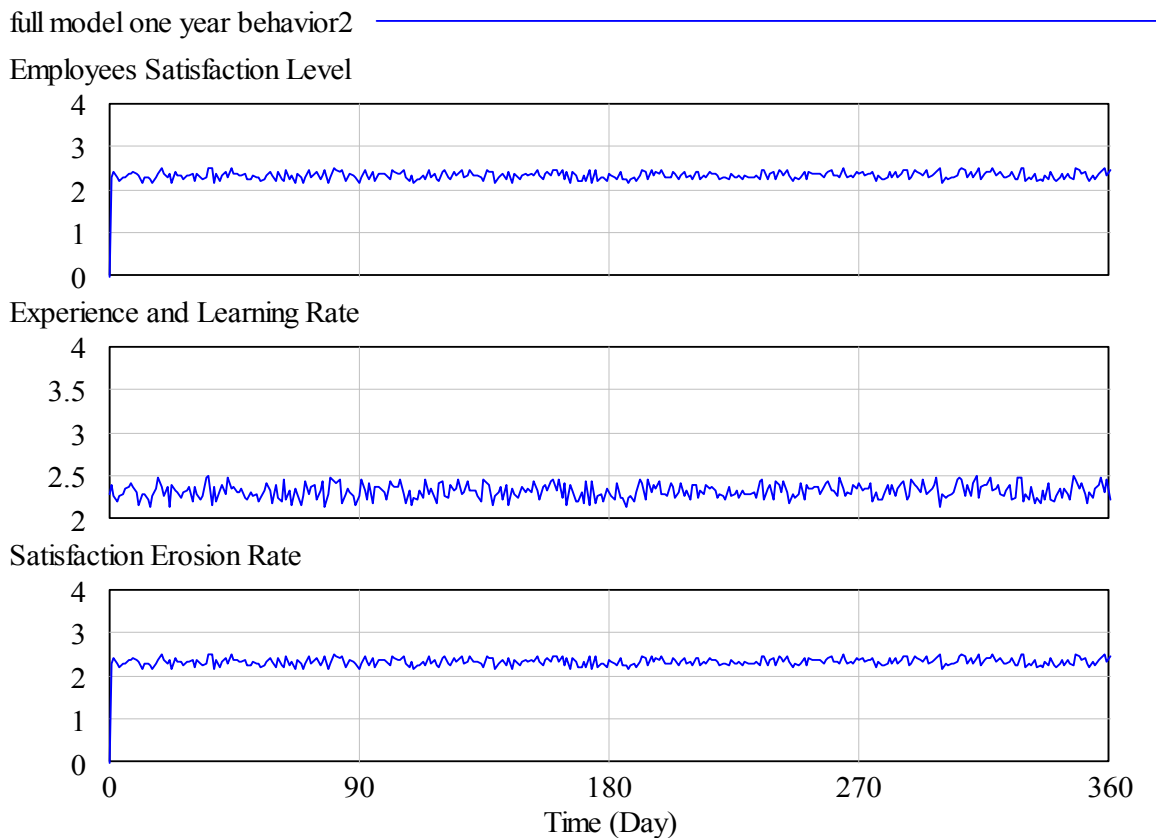


Figure 4-60: Employees Satisfaction Level Behavior over One Year

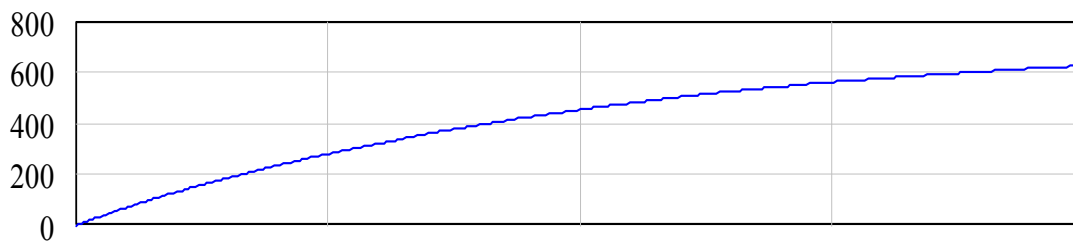
Personal Stress

Most of the days, *Stress Accumulation Rate* is on average four (these are the explanation of the questionnaire results). The *Stress Relief Rate* behavior is exponential with the ‘goal-seeking’ value of three. The *Personal Stress* behavior is also exponential,

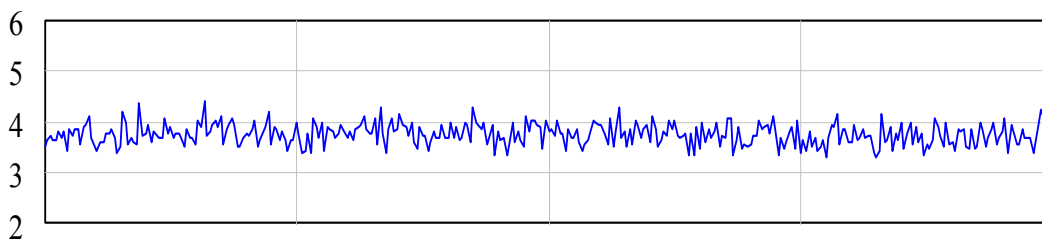
reaching almost seven hundred (Figure 4-61). Comparing these results to the personal subsystem's results shows that the results in the full model are more extreme: *Personal Stress* in the personal subsystem is not affected by employees' pressure, and therefore it does not increase to these high levels (goal-seeking to five hundred) (Figure 4-41, p.235). It is important to mention that the values of stress are not as important as their behavior. Measuring stress is not a tangible issue, but the ability to depict its behavior is more significant for this research. The decision maker should be concerned about the high level of personal stress. Section 4.6 (p. 267) presents the simulation of policy changes that includes a higher level of quality culture. This impacts positively personal stress, which exceed up to five hundred only.

full model one year behavior2

Personal Stress



Stress Accumulation Rate



Stress Relief Rate

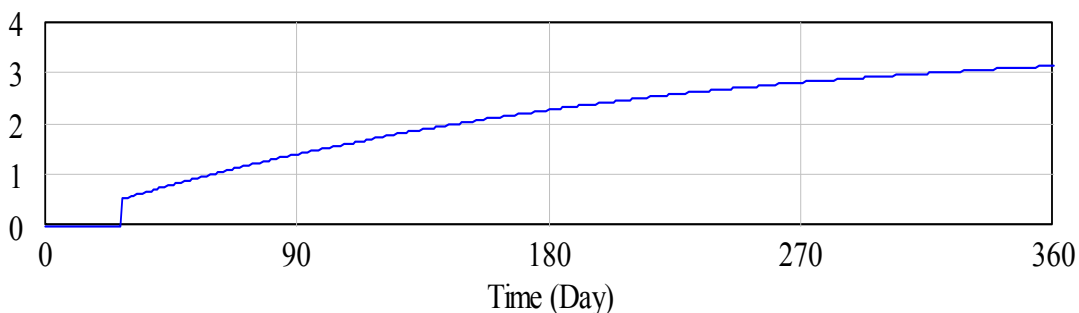


Figure 4-61: Personal Stress Behavior over One Year

Organization Commitment:

Organization Commitment oscillates between 0.10 and 0.75 most of the days. The inflow and outflow rates are similar. The results are lower in the personal subsystem (Figure 4-42, p. 236) than the results in the full model. In the full model *Organization Commitment* is affected by the other subsystems.

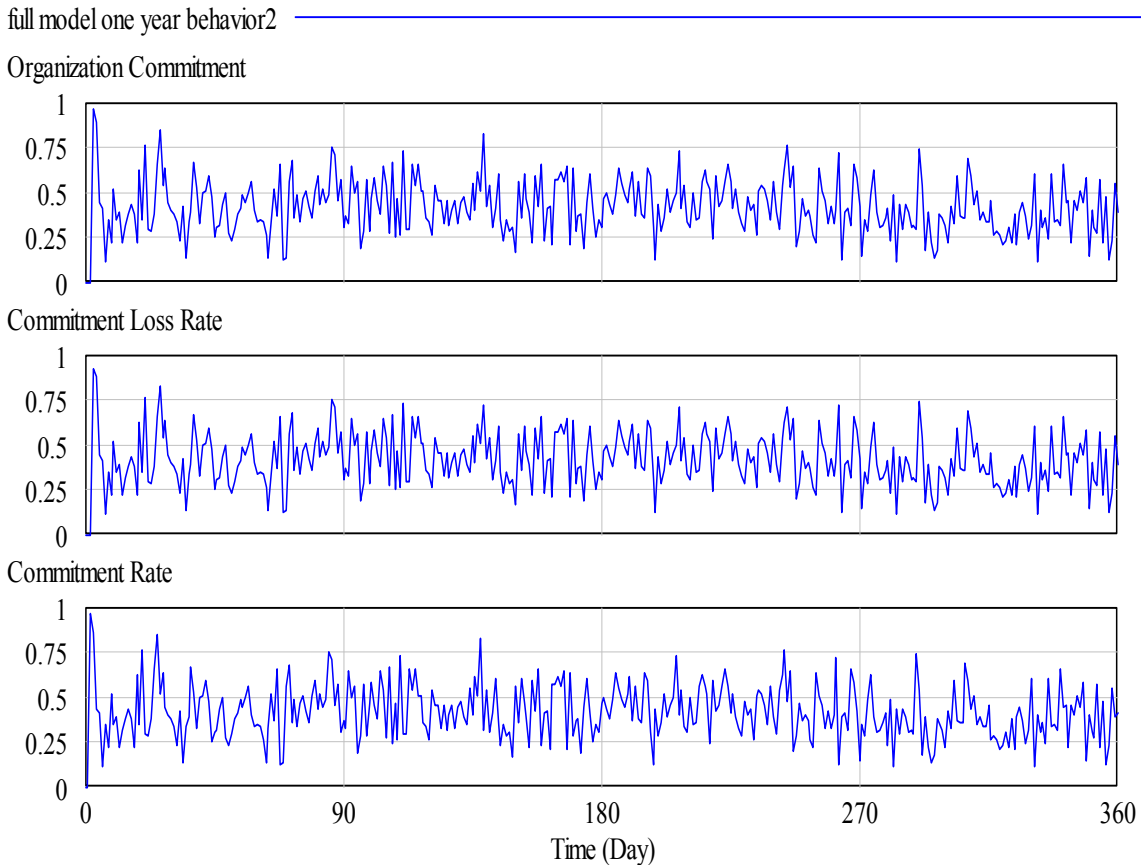


Figure 4-62: Organization Commitment Behavior over One Year

4.5 Model Validation and Sensitivity Analysis

4.5.1 Validation of System Dynamics Models in General

This model as all the models in general is only an attempt to represent the reality. It is never reality, or as Sterman emphasized: “all models are wrong...all models, mental or formal, are limited, simplified representations of the real world.” (2000, p. 846). In any case, our mind has its own peculiar mental model of the reality. Although there are many difficulties and the limitations involved in building an accurate model and validating it, it is worthwhile to invest in developing the best available model that can be used for a

particular purpose (Sterman, 2000). Developing, building and simulating a model are important steps, however they are not sufficient for approving the appropriateness of the model to the real system, or as Peterson and Eberlein argue: “there is no deductive algorithm for getting from reality to valid simulation models” (1994, p.161). Validation tests can help to improve the model, make it more tangible and more useful. The validity tests attempt to see if the model’s behavior is consistent with the behavior of the real system.

Barlas (1996) distinguishes between models that are theory-like and models that are more purely data-driven. In the case of purely correlational models according to Barlas, what matters is the aggregate output behavior. If the output of the model matches the “real” output within some specified range of accuracy, the model is assessed to be valid. On the other hand according to Barlas, “causal-descriptive models are statements as to how real systems actually operate in some aspects” (1996, p. 185). In this case, what is more crucial than generating accurate output behaviors, is the validity of the internal structure of the model (Forrester and Senge, 1980). This means that the model has to explain how behavior is generated and suggest ways of changing the existing behavior (Forrester and Senge, 1980; Barlas, 1996). A system dynamics model is considered as a causal-descriptive model and therefore validating it is much more complicated than validating the data-driven models. According to Barlas (1996), judging the validity of the internal structure of a model is very problematic, both from the philosophical and the technical point of view. Philosophically, Barlas asserts that the validity of a system dynamics model means the validity of its internal structure and Barlas (1996) and Forrester and Senge (1980), in their recent relativist/holistic philosophy argue that validation of the internal structure cannot be made entirely objective, formal and quantitative. The challenge is to design formal validation procedures and tests, which are suitable for system dynamics models, while keeping the causal-descriptive philosophical view.

Regarding formal model validation, Forrester and Senge (1980), and Barlas (1996) agree that first, it is reasonable to test the validity of the structure, and then test the behavior’s accuracy, which is done only after the structure of the model has been perceived adequately. The former includes direct structure tests and structure-oriented

behavior tests. Structure-oriented behavior tests are more suitable to formalize and quantify than the structure tests are, and therefore they are more accepted and are more useful when considering model validation (Barlas, 1996). The later includes behavior pattern tests.

Conducting tests necessitates a lot of knowledge about the real system, and it requires the ability to fabricate mathematical equations that can describe the behavior of the real system (Peterson and Eberlein, 1994). The use of VENSIM's Reality Check, which is an automatic validity tests facility of the VENSIM software, the software that is used for simulation, makes it a lot easier to expedite various tests.

4.5.2 Validation Procedure for the Firm's Model

The purpose of this research focuses in revealing the firm's reality concerning the interactions between organizational effectiveness, quality culture and employee's health. The center of this system boundary is the production subsystem. The subsystems and some of the important variables that are involved in this model can be described by the conceptual model in Figure 4-63 where only the relationships are represented and not their polarity.

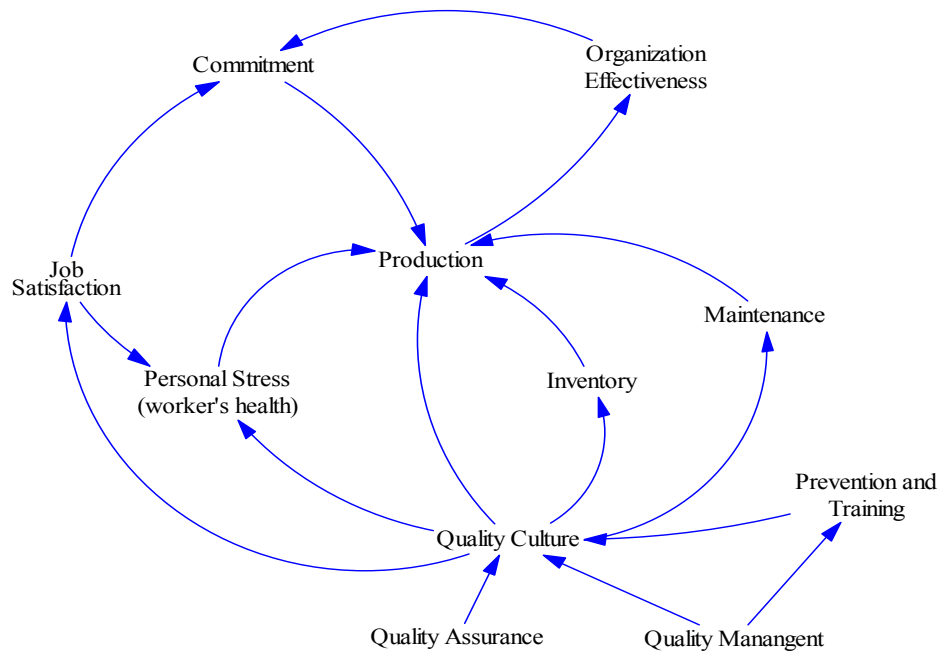


Figure 4-63: Subsystems Conceptual Model

Figure 4-63 shows us that quality culture affects most of the items which are included in this model: maintenance, inventory, production that influences organization effectiveness, personal stress (representing an important issue of workers' health), and job satisfaction, which influences commitment.

On the other hand, production is impacted by most of the other elements in this model: directly by quality culture, inventory, maintenance, commitment and personal stress, and indirectly, by job satisfaction and organizational effectiveness.

Understanding the relations between the subsystems is contingent upon choosing the appropriate validation and confidence tests. It is important to mention that validation tests will be applied only for the full model and not to the subsystem models (Peterson and Eberlein, 1994).

I will apply most of tests recommended by Sterman (2000), (Barlas, 1996), and Forrester and Senge (1980) and will explain what should be done, what is relevant or irrelevant in each case.

4.5.2.1 Boundary Adequacy

The boundary adequacy test examines whether the model boundaries include all the related subsystems that are important for the model's purpose. This test finds out if the important concepts when addressing the problem are endogenous to the model, will the behavior of the model change when model boundaries are changed, and will the changing of the boundaries influence the policy recommendations (Sterman, 2000).

In the case of the firm, as it is presented in Section 4.2 (p. 175), the group-model-building has determined what the model boundaries should be in order for the important concepts to be endogenous in the model while addressing the problem. It includes the main elements that are involved daily in the manufacturing process: production, quality assurance, maintenance, inventory and the employees. These elements and the relationships among them are described in Figure 4-63. The items that are exogenous include marketing, administration, financial administration and leadership. Marketing's influence on the model boundaries is only in the very long-term and has no impact on daily behavior of the firm. Administration deals with the employees' daily, but has no impact on the important variables of the model that are: quality, stress, pressures, etc. Financial support is not an internal part of the firm. The firm receives these services from

the headquarters of the firm's organization. Leadership was not considered as an issue to be considered as part of the model; however, due to its importance it will be discussed in Chapter Five.

4.5.2.2 Structure Assessment

Structure assessment tests check whether the model is consistent with knowledge of the real system and whether it is relevant to its purpose. It focuses on the level of aggregation and the conformance of the model to basic physical laws (Sterman, 2000).

As explained in the previous section, this model is an output of the group-model-building effort. It is the participants' description of their daily working world, and it was built in order to capture their mental models associated with their daily experience and understanding of how things are accomplished in the system. In the process of building the model, as explained in Section 4.1.5 (p. 173) and 4.1.6 (p.174), the level of aggregation has been modified several times, until the group accepted a certain level. This level of aggregation changed again while transforming the model to a formal model. Finally it was accepted again by the group participants, the CEO and other workers.

Sterman (2000) emphasizes the importance of assuring that stocks of real quantities will never become negative (p.863). Therefore the outflows from all such stocks must approach zero as the stock approaches zero. In order to guarantee that this physical law will not be violated, all the quantitative stocks in the model have a first-order negative feedback loop that restricts the outflows from the stock so the outflow is zero when the stock is zero.

4.5.2.3 Dimensional Consistency

Dimensional consistency deals with assuring that the dimensions are consistent throughout the full model. This means that the right-hand side and left-hand side of each equation are consistent dimensionally. When using VENSIM as the simulation software, dimensional consistency is required as a main condition to simulate the model. Most of the dimensional variables in this model are: tasks, days and hours, and some variables are dimensionless.

4.5.2.4 Parameter Assessment

According to Barlas (1996), parameter confirmation/assessment means "evaluating the constant parameters against knowledge of the real system, both

conceptually and numerically” (p. 190). For the model in this research there is relatively a small number of parameters. Most of the variables use random numbers (with uniform or normal distribution), based on the firm data.

Sterman (2000) suggested using partial model estimation for parameter selection. In the case of building the full model for the firm, the model development process started with partial models and later was aggregated to a full model. Parameters were initially assessed for each partial model and finally were included in the full model.

4.5.2.4.1 Production parameters

The parameter of seven is the number of major machines in production. Beadle machines are thirty five. The length of workday is considered to be 8.67 hours. The working days are five per week.

4.5.2.4.2 Maintenance parameters

The maintenance parameters are identical to the production parameters.

4.5.2.4.3 Quality assurance parameters

No parameters are included in this part of the model, except for the number of daily working hours, which is 8.67 hours.

4.5.2.4.4 Inventory and logistics parameters

No parameters are included in this part of the model, except for the number of daily working hours, which is 8.67 hours.

4.5.2.4.5 Personal parameters

There are no parameters in this part of the model.

4.5.2.5 Extreme Conditions

Sterman (2000), (Barlas, 1996), and Forrester and Senge (1980) emphasize the importance of demonstrating the model’s robustness. Extreme conditions are very useful for this purpose. If the model behaves realistically under an extreme condition, we can conclude that the model is robust. Using extreme conditions when simulating the model, enables the assessment of the plausibility of the resulting values against the knowledge of such cases in the real world (Forrester and Senge, 1980). Extreme conditions may involve imaginary situations that may not be predicted in the future but should be examined in the model in order to earn confidence in the behavior of the model.

As usual, there are infinite kinds of extreme conditions that may be tested, especially if the model is large. As I have already mentioned, it is important to select those tests that are significant to the behavior of the entire model and not for the subsystems (Peterson and Eberlein, 1994). The relationships that were tested were selected pursuant to the following decisions and preferences:

- a. The relationship connects between variables of different subsystems.
- b. The tests rely on dynamic hypotheses that express the theoretical purpose of this research namely, that the dynamic hypothesis has been presumed through the development of the model.
- c. Part of the connections that were selected has either a positive relationship with another variable or a negative one.

Peterson and Eberlein (1994) suggest using tests that outnumber equations. The following list exhibit questions that lead to the outnumbered equations designed to test extreme conditions for the model:

- If all major machines break down, the production rate has to decline to zero.
- If *Personal Stress* declines to zero, *Correct Task Completion Rate* in production should increase.
- If *Quality Culture Level* is high, it should decrease *Level of Interruptions*.
- If *Quality Culture* increases and also the *Training* variable increases, they should increase *Perceived Job Control*, which should decrease *Personal Stress*.
- If the *Problems and Malfunctions* stock is zero, it should increase *Organization Effectiveness* and *Organization Commitment* positively, which means that *Organization Effectiveness* and *Organization Commitment* should increase.

The first extreme condition deals with the case in which all the machines are down. This means that the variable *Machine Breakdown Rate* was entered with the value of seven (the maximum numbers of major machines in the firm). The expected constraint in this case is that the *Correct Task Completion Rate* and *Out of Order Completion Rate* in production will decrease to zero. The confidence of the model was ensured by this test.

The second extreme condition of behavior deals with the relationship between *Personal Stress* level and its impact on the *Correct Task Completion Rate*. It is expected that according to the dynamic hypothesis in this research (See Section 1.6.6, p.11) when

stress is lower the workers' ability to control and perform their tasks adequately is higher. The extreme condition in this case is formulated as *Personal Stress* decreasing to zero and assessing whether the *Correct Task Completion Rate* would increase. The test has passed successfully, the model behaved in accordance with the assumptions.

Quality Culture Level is supposed to have an important impact on problems and malfunctions at any firm. Detert et al. (2000) elaborate on the dimensions of quality culture, which include among others: the basis of truth and rationality in the organization and the belief about humans' motivation that leads to the performance of quality work. In the case of this firm, the *Quality Culture Level* is low and has so far no positive influence on the several variables which are supposed to be influenced positively by the level of quality culture. In order to test the model's behavior in a case in which the *Quality Culture Level* is high, the third extreme condition has been carried out. In this test, *Quality Culture Level* was given the value of one to test the impact on *Level of Interruptions*. The *Level of Interruptions* decreased as expected.

High *Quality Culture Level* which includes definitely also high level of *Training* is supposed to lead employees to *Perceived Job Control* which will lower their *Personal Stress* (Karasek and Theorell, 1990). These relationships are also compatible with theoretical dynamic hypotheses in Section 1.6.5 and 1.6.6 (p. 11). The two extreme conditions to test these relationships included giving *Quality Culture Level* the value of one, and changing the value of *Training* to value above 0.8. In this case, the *Personal Stress* declined to zero as expected.

The relationship between the *Problems and Malfunctions*, *Organization Effectiveness* and *Organization Commitment* is assumed to be inversed: when there are fewer *Problems and Malfunctions*, the *Organization Effectiveness* increases and the *Perceived Organization Effectiveness* increases therefore, the *Commitment Rate* increases as well. Two extreme conditions tested these relationships. In both of them, *Problems and Malfunctions* was set to zero. *Organizational Effectiveness* increased and so did the *Commitment Rate*. The model was found suitable and confident under these extreme conditions (Appendix P).

4.5.2.6 Sensitivity Analysis

Sensitivity analysis is used to test the degree of certainty of the assumptions which underlie the model. Sterman (2000) recognizes three types of sensitivity: numerical sensitivity, behavior sensitivity and policy sensitivity. Numerical sensitivity is more likely to be important in physical-based models when precision of relationship between variables is tremendously important. In models that deal with human systems, the behavioral tests matter a lot more than the numerical ones (Sterman, 2000). Policy sensitivity matters when a change in assumptions might withhold the expected and accepted results of a proposed policy.

In this research, the most important type of sensitivity to analyze is the behavior sensitivity of the model. “The behavior sensitivity test ascertains whether or not plausible shifts in model parameters can cause a model to fail behavior tests previously passed. To the extent that such alternative parameter values are not found, confidence in the model is enhanced” (Forrester and Senge, 1980, p.221).

Sensitivity tests are performed by changing the values of model parameters in order to observe the effect of these changes on model behavior. VENSIM provides the opportunity to simulate multivariate sensitivity simulations, meaning hundreds of simulations can be performed, with constants sampled over a range of value, and output stored for later analysis (VENSIM, 5.4). This is also known as Monte Carlo simulation. The software uses the probability distribution that characterizes the possible value for each parameter to represent the best worth and most prospective simulation results (VENSIM, 5.4). Each Monte Carlo simulation was simulated with two hundred iterations.

The model contains four parameters: the number of major machines, the number of beadle machines, the length of a working day and the number of work days per week. (See Section 4.5.2.4, p. 257)

The sensitivity tests included the following changes: the number of major machines was defined as a random normal variable with a minimum of five machines, maximum of nine machines, a mean of seven machines and a standard deviation of one machine. The number of beadle machines was defined as a random normal variable with a minimum of thirty-three beadle machines, a maximum of thirty-eight beadle machines,

a mean of thirty-five machines, and a standard deviation of one beadle machine. The number of working hours per day was defined as a random uniform distribution with the minimum value of eight and a half hours and the maximum value of nine hours per day. The workweek parameter was defined as a random normal variable of three days per week as the minimum and seven days per week as the maximum, with a mean of five days per week and standard deviation of one day.

The decision whether to use normal distribution or uniform distribution generated the probable distribution of the parameter in the real system. The numbers of machines in the firm for both; the main machines and the beadle machines, are the numbers of the highest probability, while having a low probability to use fewer or more machines. Therefore the decision was to use normal distribution. The number of working hours per day is considered 8.67, but is subject to change within less or more minutes. Therefore the decision was to use the uniform distribution. The number of workday per week is also a constant, but is subject to change according to the season or because of a holiday (See Section 4.3.1.2, p.196). Therefore the decision was to use the normal distribution.

The sensitivity graphs illustrate the amount of uncertainty associated with each variable. The percentage delimitations show the confidence bounds. VENSIM software uses four kinds of percentage delimitations: 100%, 95%, 75% and 50%. For each percentage, the confidence bounds show the associated probability that the variable will have (a value between the boundaries that delimit that percentage).

The simulation was performed for a hundred days only in order to have clearer results on the graphs. For each variable whose behavior is displayed over a period of time, the graph is generated. The confidence bounds are shown for all the output values that were generated when the four parameters were randomly varied according to their distributions.

The *Problems and Malfunctions* stock is strongly linked by *Correct Task Completion Rate*. The relationship between the two variables is impacted by: (a) the number of unavailable machines (*Machine Gap*), (b) the *Time Devoted for Urgent Tasks in Quality*, (c) the *Level of Interruptions* in inventory and (d) the amount of *Sickness*. We assume that *Problems and Malfunctions* stock will increase when the above variables increase. Also we assume that if we allow the parameters of time (hours per day and

workdays per week) and the number of machines available to vary, there will be a higher oscillation of the *Problems and Malfunctions* behavior. Figure 4-64 shows the dynamic confidence bounds for *Problems and Malfunctions*. It shows that the fluctuation is higher when these parameters are varied and conversely, there is less fluctuation when they are kept constant (the blue line). The variability in *Problems and Malfunctions* in most of the days has fifty percent probability to have a value between one and a half tasks and four tasks. This is similar to the value of this variable in the model with parameters' values, as is depicted in Figure 4-48. When the oscillation rate is high, the probability to have greater variability for *Problems and Malfunctions* is low. The uncertainty increases when the oscillation is less frequent (for example; days 20-22, days 32-36 and days 79-83).

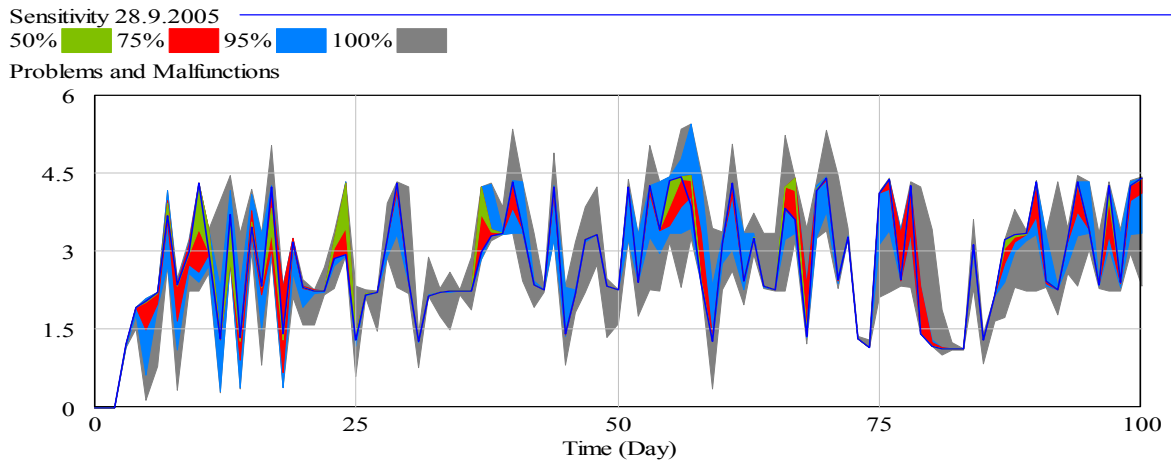


Figure 4-64: Dynamic Confidence Intervals for Problems and Malfunctions

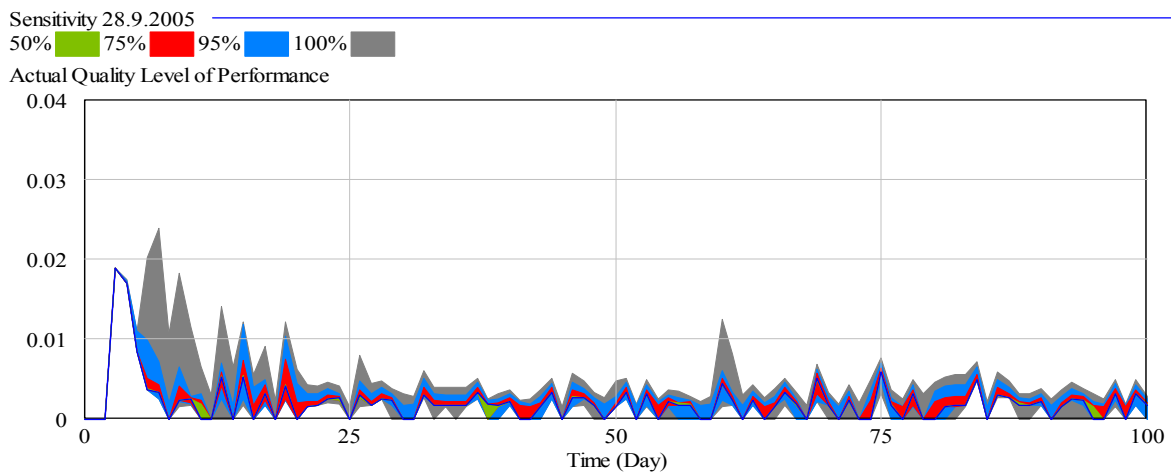


Figure 4-65: Dynamic Confidence Intervals for Actual Quality Performance Level

Actual Quality Performance Level is a variable in loop R6. It is influenced by the level of *Organization Commitment*, which in turn is impacted by the amount of *Problems and Malfunctions* in production. We assume that the days in which there is a greater probability of variability in *Problems and Malfunctions* there will also be a greater probability of the variability in *Actual Quality Performance Level*. For instance, the variability of the *Problems and Malfunctions* hundred percent band in several days is very high (for example; days 20-22, days 32-36 and days 79-83). In these days, the *Actual Quality Performance Level* hundred percent band is wider than in most other days and is higher. The days with uncertainty of *Problems and Malfunctions* impact the uncertainty of *Actual Quality Performance Level*. The result of the simulation with the constants appears in the boundary of the fifty percent chance (Figure 4-65).

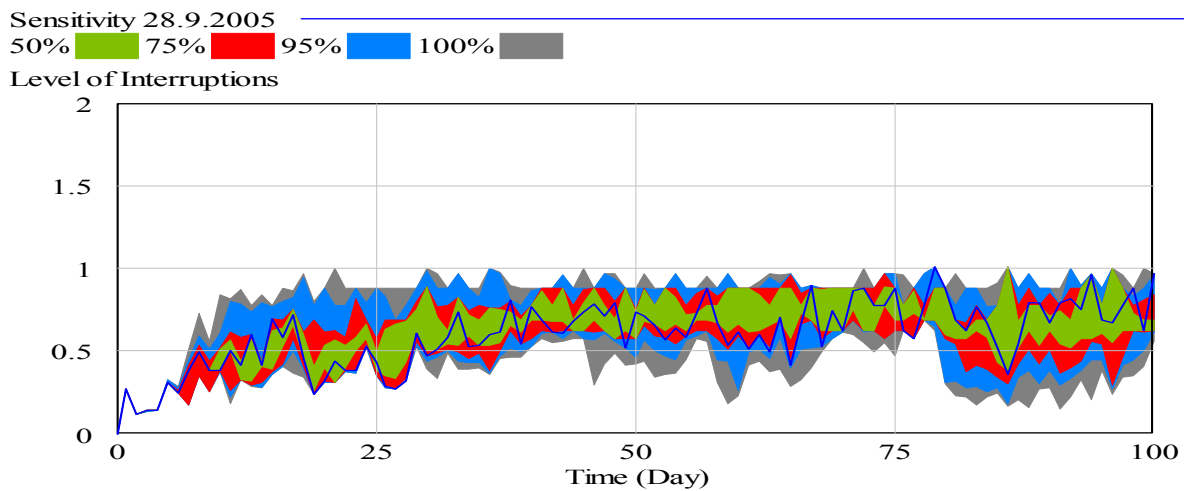
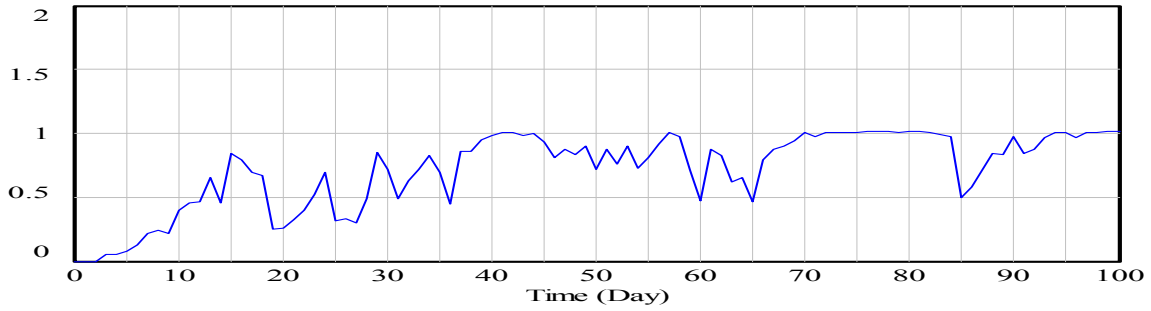


Figure 4-66: Dynamic Confidence Intervals for Level of Interruptions

Figure 4-66 shows the dynamic confidence bounds for *Level of Interruptions*. The variability of the *Level of Interruptions* in the first days is very small. The confidence interval widens after several days. This increase in uncertainty might be due to *Production Workers Pressure on Inventory for Immediate Service*. This variable impacts the *Level of Interruptions* and increases also during this period (Figure 4-67).

Pressure on Inventory by Production Workers for Immediate Service



Pressure on Inventory by Production Workers for Immediate Service : SeDimensionless2005

Figure 4-67: Production Workers Pressure on Inventory for Immediate Service Behavior

According to Figure 4-66, there is a fifty percent chance that the percentage of the interruption tasks in inventory runs between 0.5 percent and 0.80 percent.

Machine Breakdown Open Tasks stock is usually in the real system less than one machine per day (between 0.01-0.8 according to Figure 4-51). When the number of machines is changed, we assume variability in the breakdown values. Since the number of machines for the sensitivity tests is normally distributed with the means of the constant value (seven machines), our assumptions are: (a) the distribution of the fluctuation will be similar for all the dynamic confidence intervals, but with wider ranges, especially to the higher boundary (b) the results of the constant simulation will be in the fifty confidence bounds. As depicted in Figure 4-68, most of the days *Machine Breakdown Open Tasks* has fifty percent probability that its value will be very similar to the results of this variable in the model with parameters' values. Figure 4-68 shows that the *Machine Breakdown Open Tasks* fluctuation is almost similar for the each dynamic confidence interval.

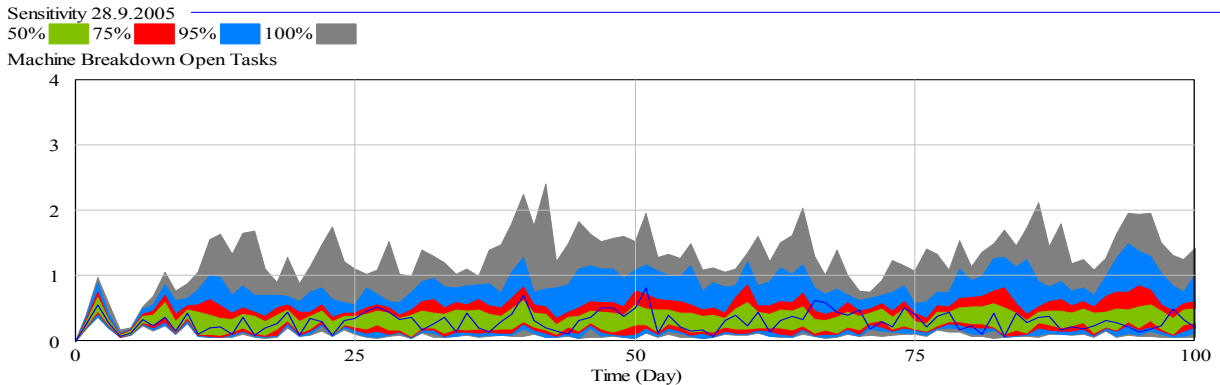


Figure 4-68: Dynamic Confidence Intervals for Machine Breakdown Open Tasks

The probability for more machines breakdown will likely impact the *Pressure on Employees*, the variable that is influenced by the available number of machines.

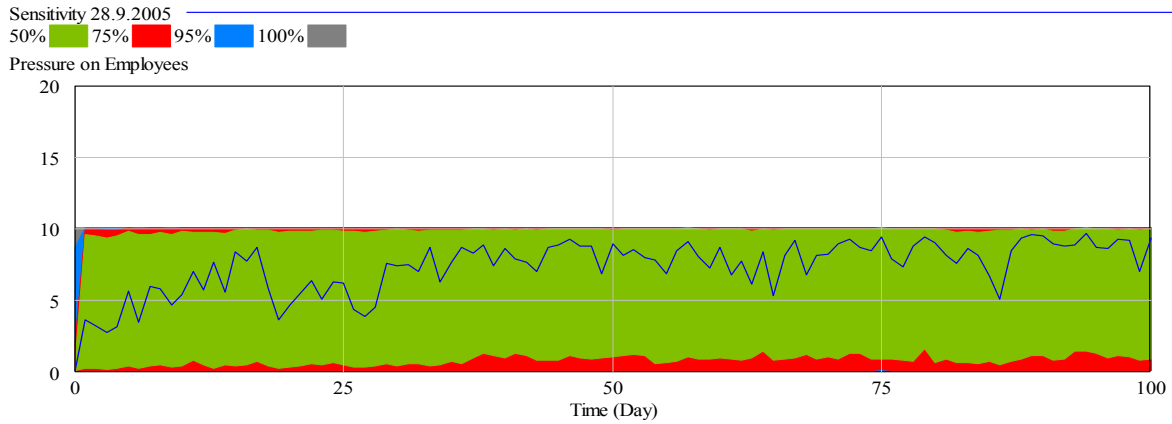


Figure 4-69: Dynamic Confidence Intervals for Pressure on Employees

Figure 4-69 shows that the bands of all the confidence bounds are almost similar in their width. Since *Pressure on Employees* is a non-linear variable with values between zero and ten, its variability is expected to oscillate between zero and ten. The results of the constants simulation in the model cause this variable to vary continuously between zero and ten (in most cases, above zero).

Figure 4-70 and Figure 4-71 show the sensitivity behavior of *Personal Stress* as a result of the changes that were made to the constants. The behavior of *Personal Stress* is exactly the same, but the confidence interval widens along the period. Figure 4-71 shows that the increase is not linear; it increases faster in the beginning than it does later. If we increase the time horizon, this tendency will continue.

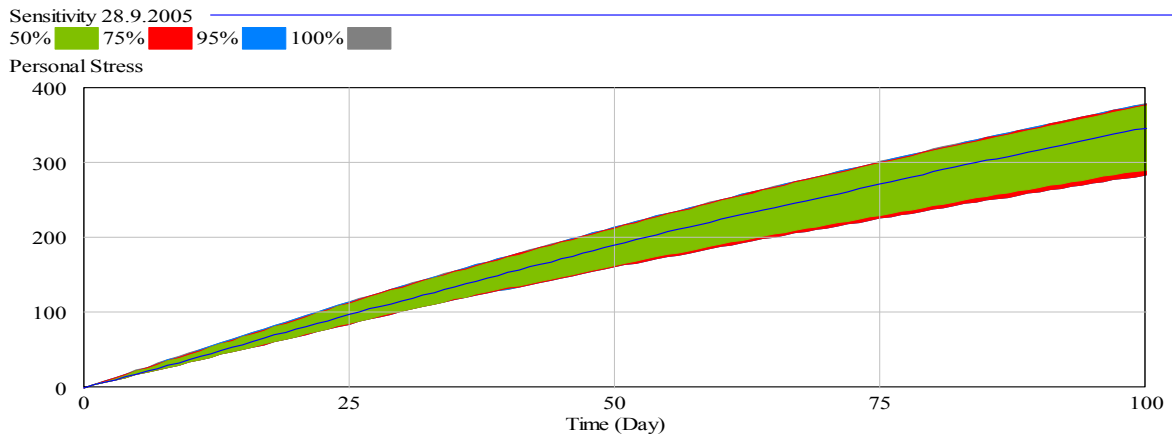


Figure 4-70: Dynamic Confidence Intervals for Personal Stress

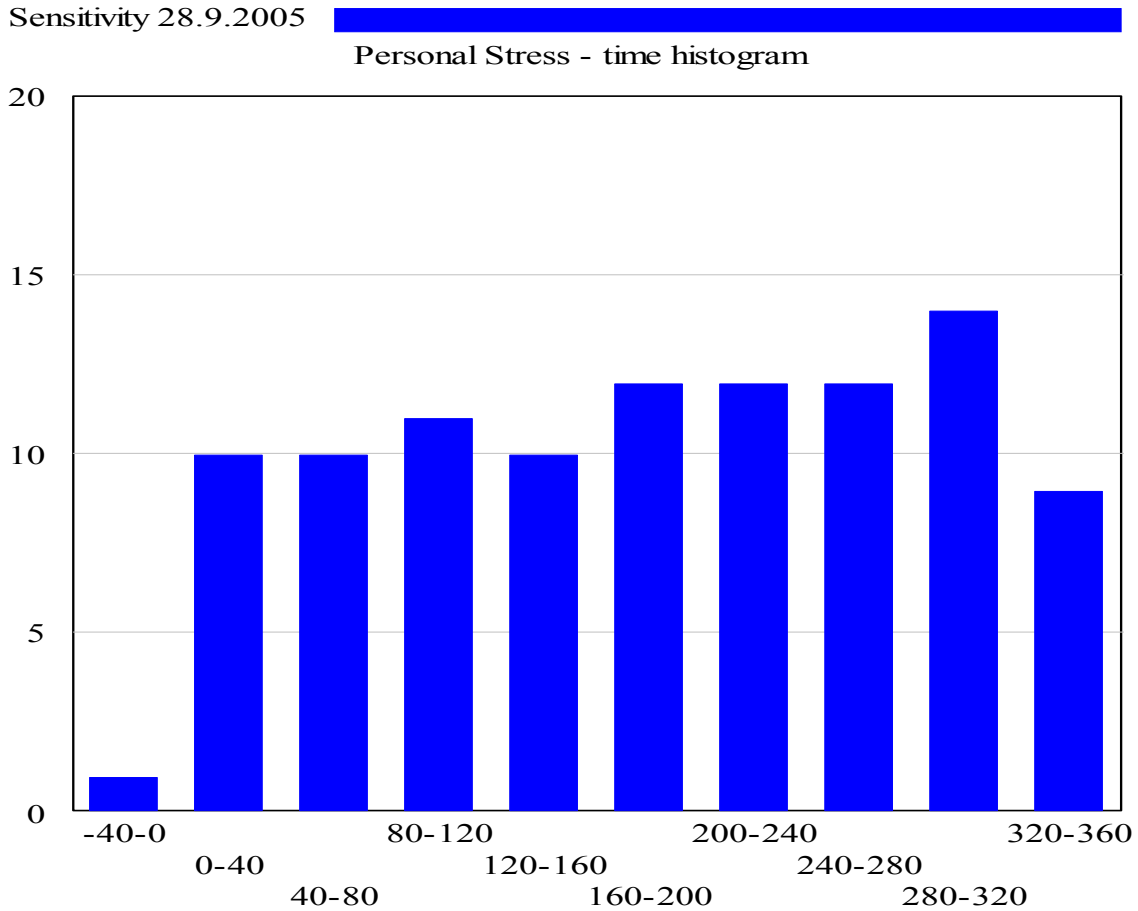


Figure 4-71: Personal Stress Histogram Sensitivity Output

The results of the sensitivity tests show that changes of the few parameters that are used in the model generate sensitivity for those variables that are influenced greatly by those parameters, like *Problems and Malfunctions* and *Machine Breakdown Open Tasks*. Variables that are less influenced by these special parameters have a more stable behavior, like *Personal Stress*. As mentioned before, the use of parameters in the model was limited to avoid measurement errors and because of the nature of the production process.

4.6 Model Results, Summary and Policy Analysis

The results of the full model, the subsystems, and the real system's information are summarized in Table 4-1 (results per day).

Model Variables		Subsystem Results	Full Model Results	Real System Information	Comments
<i>Production Subsystem</i>	<i>Orders</i>	3-4	3-4	3-6	Affected by other subsystems
	<i>Production Tasks</i>	3-6	3-6	3-6	
	<i>Correct Task Completion Rate</i>	2-5	1-5	2-5	
	<i>Out-of Order Tasks Completion Rate</i>	0-1	0-2	1-3	Affected by other subsystems
	<i>Pressure of Employees</i>	0.25	2.5-10	Not measured	
	<i>Problems and Malfunctions</i>	0-1	0.2-2.5	1-3	
<i>Maintenance Subsystem</i>	<i>Setup Tasks</i>	0-4 (rarely 4-7)	0-4 (rarely 4-8)	Average 0-5	Affected by <i>Quality Culture Level</i>
	<i>Corrective Maintenance Tasks</i>	20-60	15-30	Average 20-32	
	<i>Machine Breakdown Open Tasks</i>	0-0.8	0-0.8 (rarely 1)	0-2	
	<i>Beadle Machines Breakdown Open Tasks</i>	0-4 (rarely 4-5)	0-2 (rarely 2-6)	0-4	
<i>Quality Assurance Subsystem</i>	<i>Open Quality Tasks</i>	2-10	2-10	2-10	Affected by <i>Quality Culture Level</i>
	<i>Urgent Quality Tasks</i>	Less than 4.5	Less than 4.0	Above 5 sometimes	
	<i>Time Devoted to Urgent Quality Tasks</i>	0.3-0.6 (2.6-5.2 hours)	0.3-0.5 (2.6-4.3 hours)	0.3-0.8 (2.6-6.9 hours)	Affected by <i>Quality Culture Level</i>
	<i>Quality Culture Level</i>		0-0.35		Not included in a subsystem

Model Variables		Subsystem Results	Full Model Results	Real System Information	Comments
<i>Inventory and Logistics</i>	<i>Open Tasks in Inventory</i>	5-20 (rarely 20-25)	15-25	15-25	Affected by <i>Quality Culture Level</i>
	<i>Customers Waiting for Service</i>	3-7 (rarely 7-8)	3-8	More than 5	
	<i>Level of Interruptions</i>	0.2-0.9 (Percentage)	0.1 -0.7 (Percentage)	More than 0.5	Affected by <i>Quality Culture Level</i>
<i>Personal Subsystem</i>	<i>Employees Satisfaction Level</i>	Average 2.5	Average 2.5		Measured using a questionnaire
	<i>Personal Stress</i>	Goal-seeking 500	Goal-seeking 700		Affected by Employees Pressure and by <i>Quality Culture Level</i>
	<i>Organization Commitment</i>	0-0.35	0.10-0.75		Affected by other subsystems

Table 4-1: Model's and Subsystems' Results

In summary, the results of the full model are similar to the results of the subsystems as long as the variables are not affected by other subsystem's variables. Much of the subsystems' variables behavior and the real system's variables behavior are alike.

In order for the firm to stay in business, it is committed to improve itself in two directions: 1) to improve the quality level of all the processes that maintain production, and 2) to be effective by preserving low costs and staying competitive. The results of the model show certain outcomes that necessitate attention. Comparing the full model's results to the subsystems' results, we notice the increase of the *Out of Order Tasks Completion Rate* and the decrease of the *Correct Task Completion Rate* in switching to the full model. These results do not contradict the real system's values for these variables. Some of the variables that are impacted by *Quality Culture Level* despite its

low values are decreasing. It includes: *Corrective Maintenance Tasks*, *Urgent Tasks in Quality*, *Time Devoted to Urgent Tasks*, *Open Tasks in Inventory* and *Level of Interruptions*. It is important to note the following: the increase of *Personal Stress* in the full model compared to the subsystem's model, the increase of *Pressure of Employees* in the full model compared to the subsystem's model and the low degree given to the *Quality Culture Level*. The results underscore the interrelationship between the subsystems' variables created by positive feedback loops (for instance; loop R9 provides the connection between production and inventory subsystems).

In order to make better decisions regarding what policies to implement, it is crucial to understand the behavior of the system. The improvement of the problematic behavior of the real system is actually the main goal of the whole effort of modeling. The final objective of the model is to find robust policies so that variations in the model's parameters or structure do not influence the policy (Richardson and Pugh, 1981). Changing a value of a parameter may act as a test for policy change in the real world. Such parameters are considered policy parameters, since their values are within the control of the decision makers in the real world (Richardson and Pugh, 1981). In our research, only few parameters were used, as explained in Section 4.5.2.4 (p. 257). It includes the number of major machines, the number of beadle machines, the length of workday and the number of working days per week. Out of these four parameters only the number of major machines can have an influence on policy. The length of workday and the number of working days per week are subject to labor laws. The number of beadle machines is less influential on the work pressure and on the work quality. The firm is well aware of the importance of the major machines, but it is not in the position of investing in their purchase at the present.

Considering structural changes as policy alternatives involves adding new feedback loops that alter or extend the present feedback structure of the system. Some of these options include: adding policy parameters, changing a policy parameter in the midst of a simulation test, or adding new loops representing new actions or information flow that improve system's behavior. The purpose of this research is to improve the quality culture, workers' health and organizational effectiveness through the understanding of the relationships between them. The policy alternatives introduced

hereby, draw on the quality culture dimensions according to Detert et al. (2000) and on TQM's philosophy according to Hackman and Wageman (1995).

TQM's philosophy rests upon four assumptions, one of which concerns senior management. "Because senior managers create the organizational systems that determine how products and services are designed and produced, the quality-improvement process must begin with management's own commitment to total quality. Employees' work effectiveness is viewed as a direct function of the quality of the systems that managers create." (Hackman and Wageman, p. 311, 1995). Leadership is considered essential for any change and improvement (Deming, 1986; Drucker, 1992). Therefore, leadership is an essential variable in a model dealing with improvement of quality culture in an organization.

Changing organizations' policy in order to improve the quality culture includes short-term objectives as well as long-term objectives. The short-term objectives are in fact the tools with which the long-term ones will be later achieved. It includes relationships with the workers (internal customers) and with the external customers (customers and suppliers). According to the internal customers, most important is to improve workers' motivation, workers' training and the organization's learning.

The policy changes in the model include: (a) adding *Top Management* variable as an essential part of *Quality Culture Level* with a random uniform value with a means of 0.8 and standard deviation of 0.1, (b) workers' motivation (*What Motivated Humans*) was changed to a random uniform value between 0.7 and 0.9, (c) learning (*Learning and Continuous Improvement*) was changed to a random uniform value between 0.7 and 0.9, (d) and *Relationship with Environment* was changed to a random uniform value between 0.6 and 0.8. Furthermore, the *Training* variable was changed to a stock (*Training Level*) with an inflow going out from the *Open Quality Tasks* stock (See Appendix Q).

Figures 4-72 and 4-73 depict the test that represents new information concerning the *Quality Culture Level* and the *Training Level* variables.

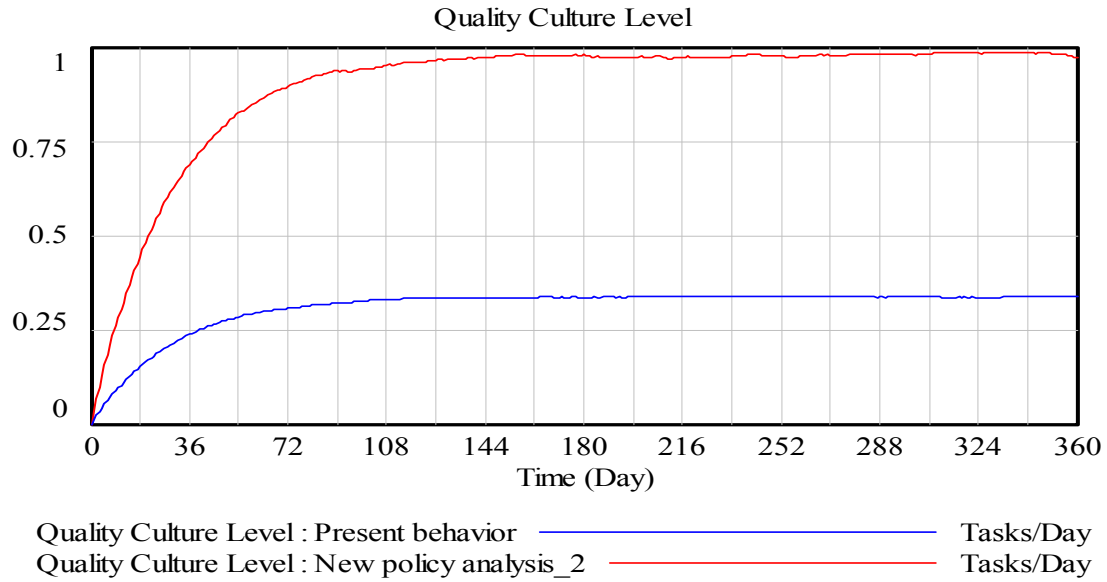


Figure 4-72: Quality Culture Level Modified for a Policy Analysis Test

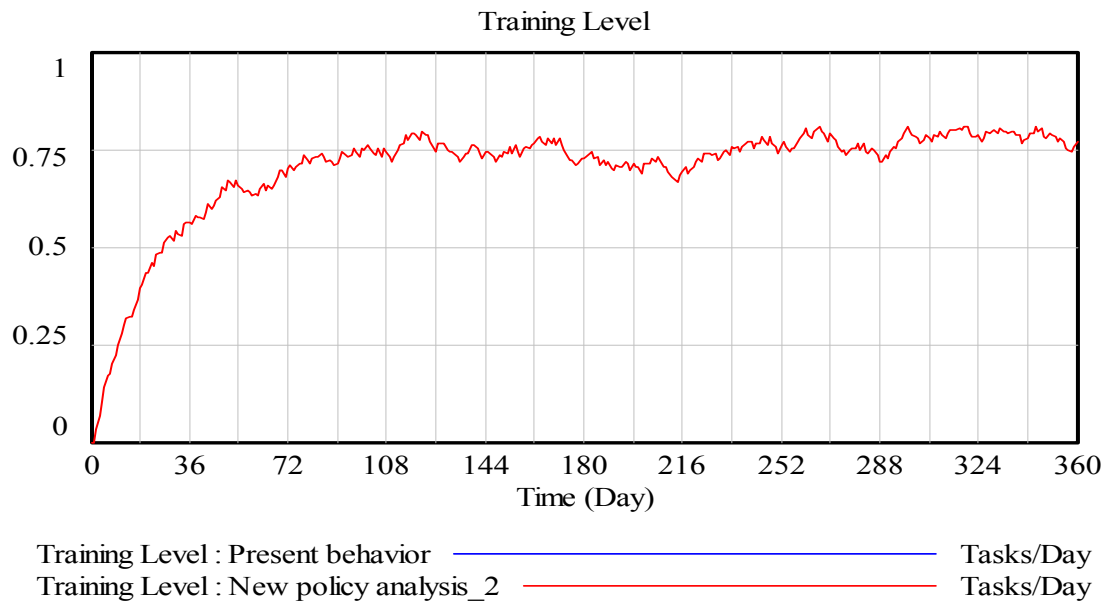


Figure 4-73: Training Level Modified for a Policy Analysis Test

As a result of the modifications in *Quality Culture Level* and in *Training Level*, *Perceived Job Control* increases, causing *Personal Stress* to increase at a slower rate than in the previous case (Figures 4-74 and 4-75).

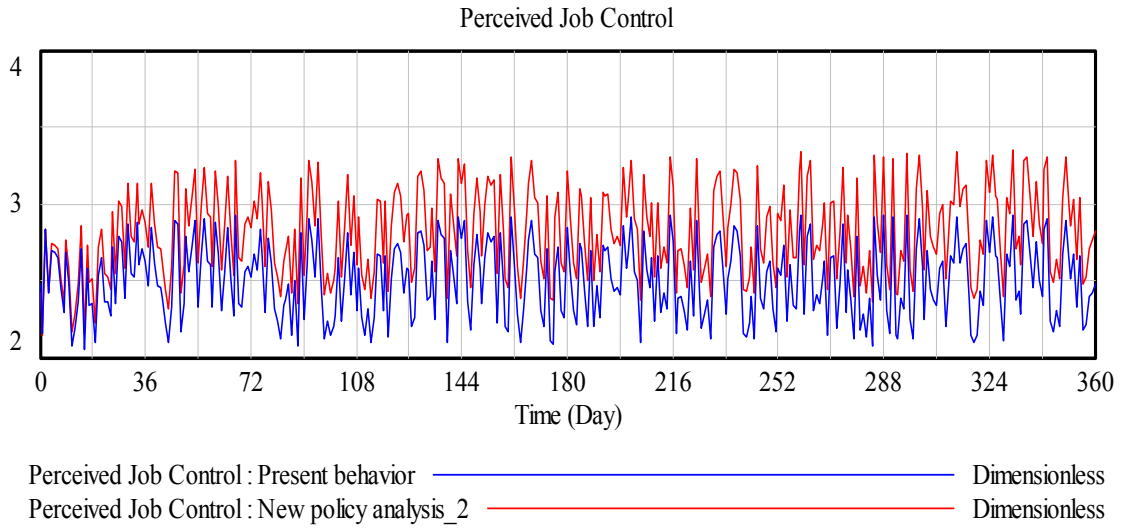


Figure 4-74: *Perceived Job Control* New Behavior Resulting from Policy Change

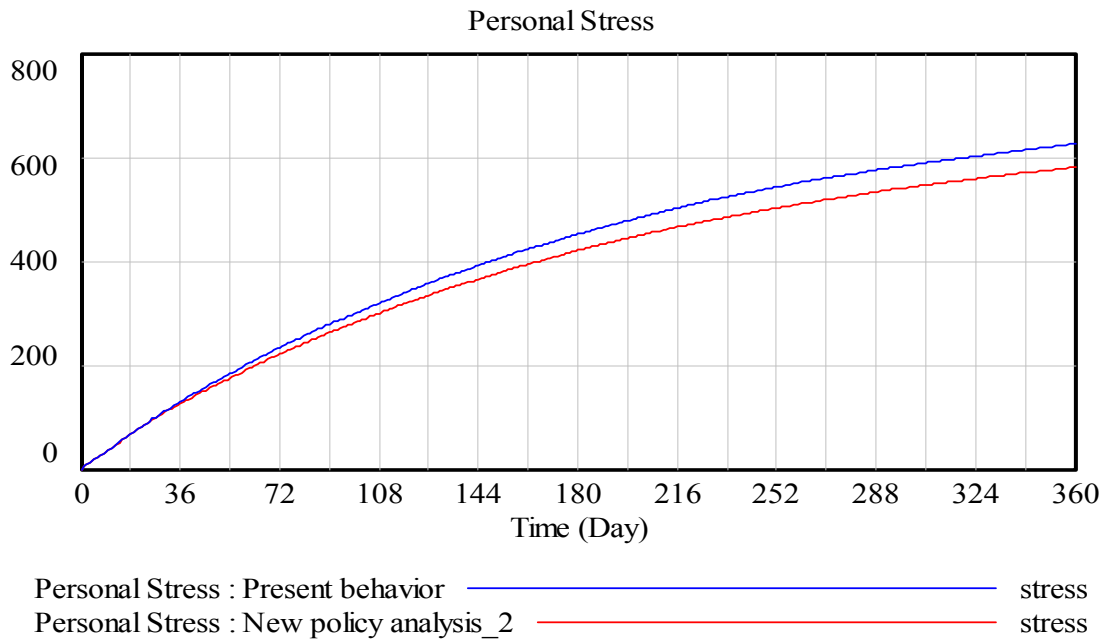


Figure 4-75: *Personal Stress* New Behavior Resulting from Policy Change

Urgent Quality Tasks Arrival Rate decreases, causing the *Urgent Quality Tasks* to decrease (Figure 4-76).

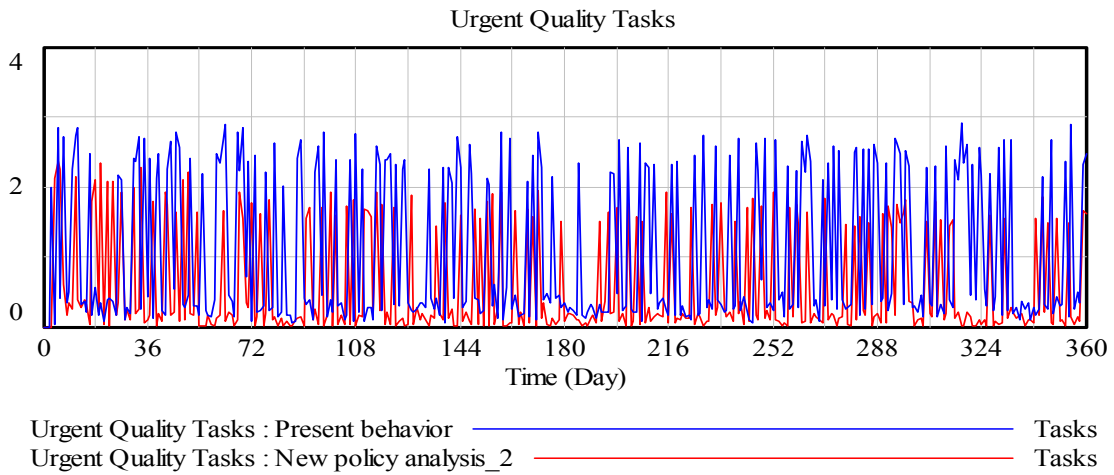


Figure 4-76: Urgent Quality Tasks New Behavior Resulting from Policy Change

CMT (Corrective Maintenance Tasks) Arrival Rate decreases causing the *Corrective Maintenance Tasks* to decrease (Figure 4-77).

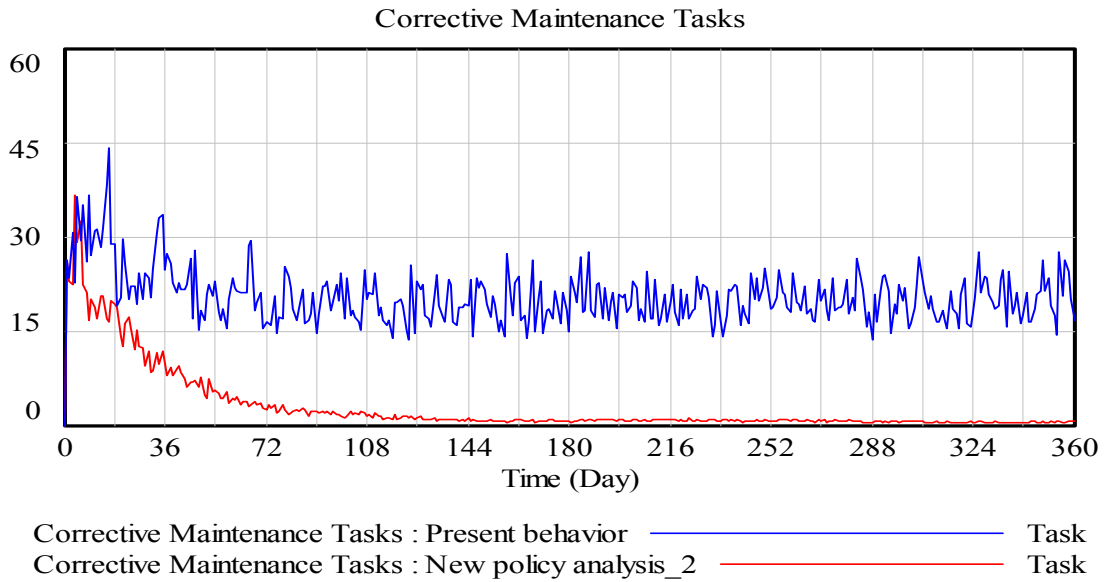


Figure 4-77: Corrective Maintenance Tasks New Behavior Resulting from Policy Change

Level of Interruptions is decreasing and *Correct Task Completion Rate* is increasing, causing the decreasing of *Problems and Malfunctions* (Figures 4-78, 4-79 and 4-80).

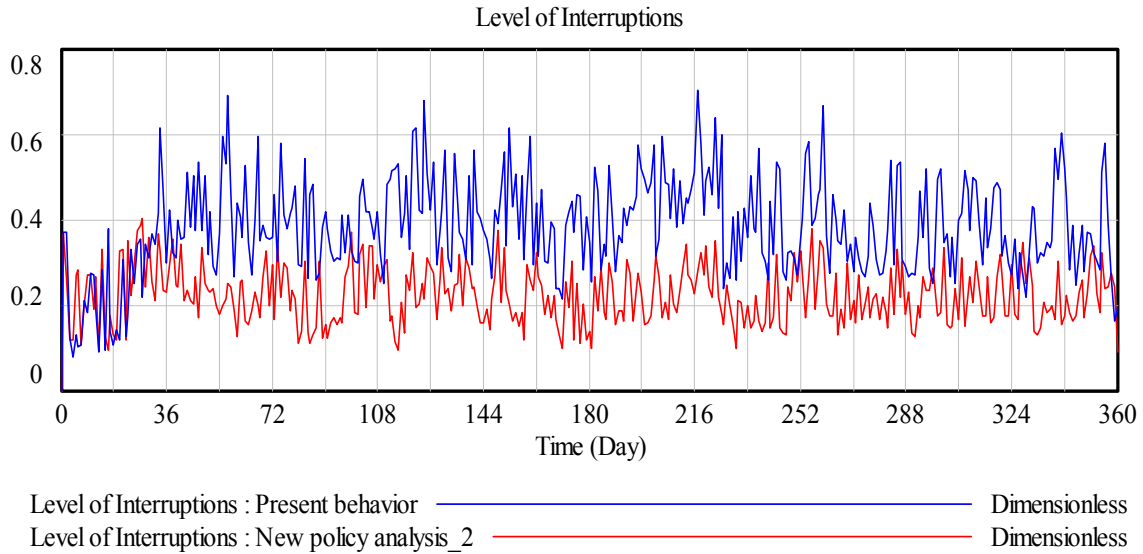


Figure 4-78: *Level of Interruptions* New Behavior Resulting from Policy Change

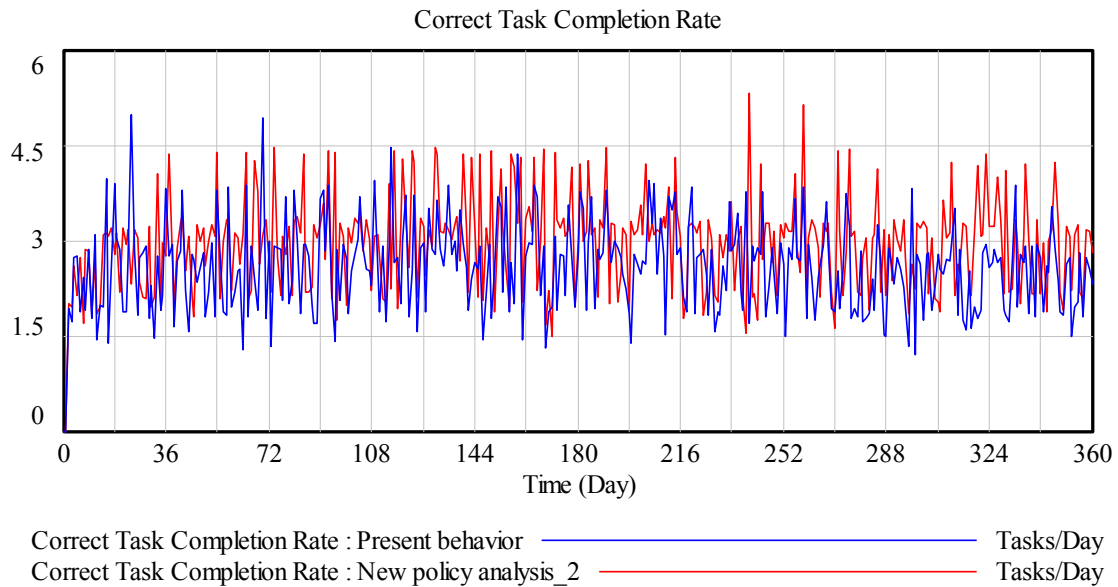


Figure 4-79: *Correct Task Completion Rate* New Behavior Resulting from Policy Change

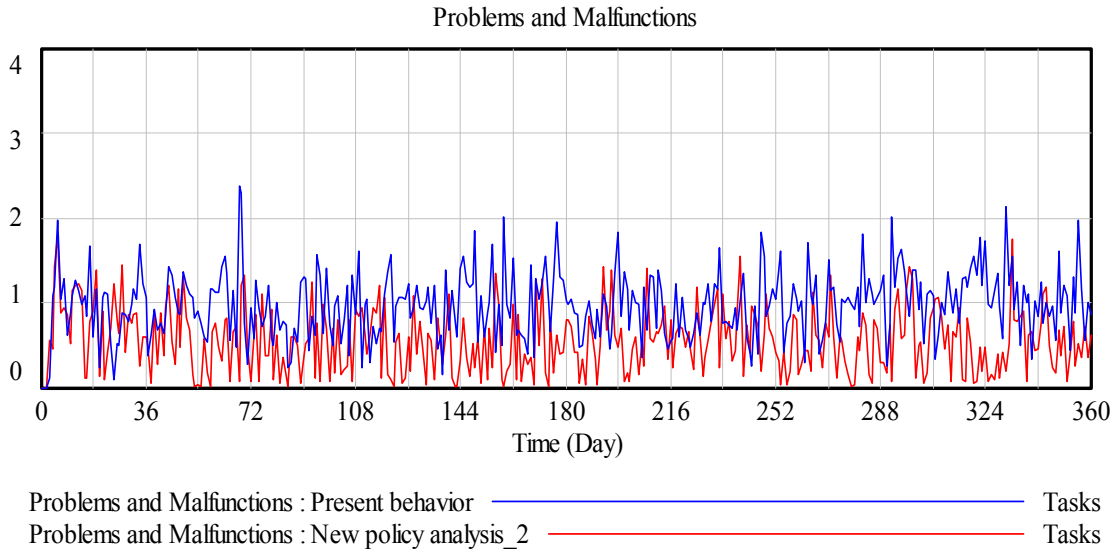


Figure 4-80: Problems and Malfunctions New Behavior Resulting from Policy Change

The decrease of *Problems and Malfunctions* increases the *Organizational Effectiveness* and *Perceived Organizational Effectiveness* (Figure 4-81)

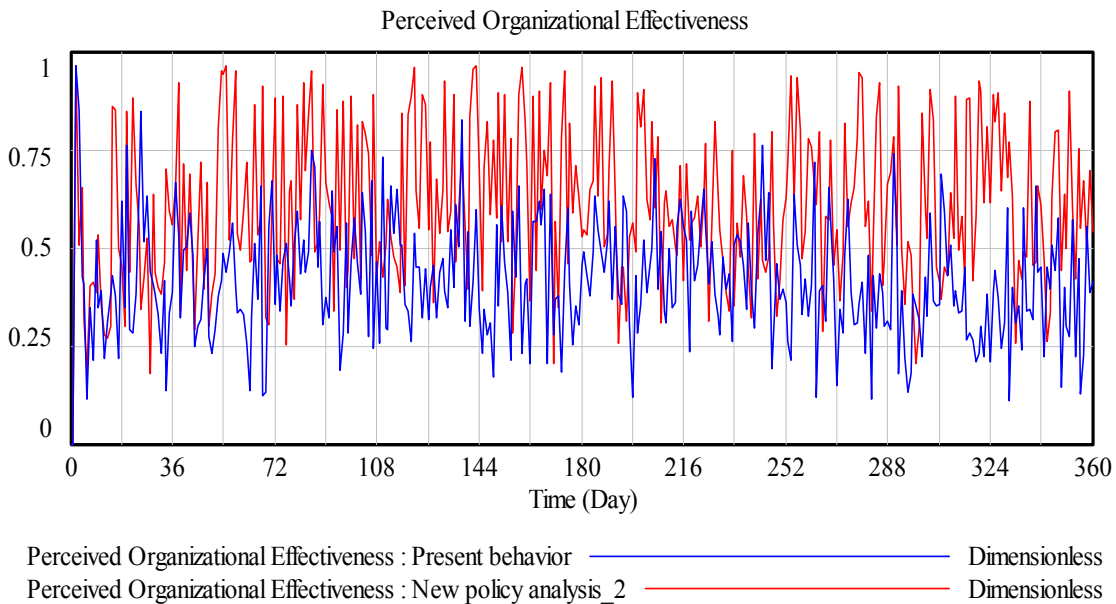


Figure 4-81: Perceived Organizational Effectiveness New Behavior Resulting from Policy Change

The increasing of *Perceived Organizational Effectiveness* increases the Organization Commitment (Figure 4-82).

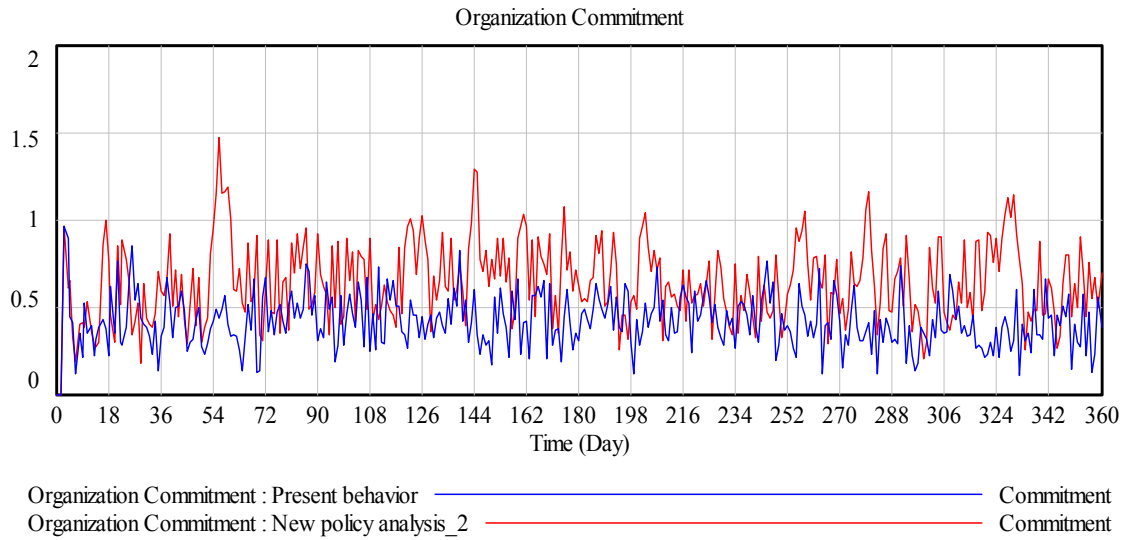


Figure 4-82: *Organization Commitment* New Behavior Resulting from Policy Change

This test reveals the changes that have to be implemented in order to improve the system's behavior. In this research, the changes were not implemented.

Chapter 5

Summary, Conclusions and Recommendations

5.0 Introduction

The motivation to research the relationship between quality culture and employees' health and how together they influence organizational effectiveness stemmed from the lack of research in the literature with respect to these relationships. Both schools of thought, i.e., the performance-oriented school and the humanitarian school acknowledge the relationship between organizations and individuals and the responsibility of one to another. However, no schools provide effective approaches that can be useful when enhancing quality culture, employees' health and organizational effectiveness concurrently.

The aim of this research was to provide a new framework, holistic in its approach that focuses simultaneously on promoting organizational and employees' outcomes, assuming that there should be a balance between these two that would benefit both in the long-run (Beer, 1980; Sutermeister, 1976; Rosen, 1992; Karasek and Theorell, 1990). The proposed framework is based on the theory of systems thinking and it has used the system dynamics approach. The system dynamics approach enables the understanding of the dynamic relationship among the various variables in the organization when linking organizational effectiveness, quality culture and employees' health. The proposed framework provides the basis for learning and for enterprises to adapt to change as required by their present organizational realities.

5.1 Summary

The field research has been conducted at a firm that provides a service of mixing powdered blends and packages them for distribution. The type of food handled by the firm dictates the high level of quality standards necessary to remain in business. The firm is also committed to maintain high effectiveness (less defective products, lower production costs, less waste) in order to remain profitable while at the same time keeping costs at a minimum. Preserving low costs in order to stay profitable affects the

requirements necessary to achieve high quality level of the products, which in turn affects employees' confidence in the work place, their sense of participation, their motivation and their desire to learn and advance. All of these characteristics positively influence employee's satisfaction and negatively affect stress and dissatisfaction. Maintaining a high level of product quality while using temporary employment and low salaries has caused many problems and has decreased profitability. In part, the purpose of this research was to analyze and understand the firm's problems by applying a system dynamics approach and creating a model of the system. Once the model was created and simulated, it provided the opportunity to understand the behavior of the real enterprise and to study how organizational changes can affect the dynamic behavior of the enterprise.

More specifically, through the use of system dynamics modeling process, we examined the dynamic interactions between quality culture, employee health and organizational effectiveness. This gave an opportunity for management to gain insights of the dynamic behavior of the organization and to make the best decisions about organizational values and management practices that enhance both organizational effectiveness and employees' health.

The process of building the model started with the design of group model-building process. It included the decision to use a quantitative approach in order to achieve a full understanding of the system's behavior. The CEO and I chose the nine participants that were involved in the modeling sessions after interviewing many of the workers. The process of building the model included nine sessions in which the conceptual model was built and the main stock and flow variables were chosen. The stage of formalizing and eliciting knowledge was done with the participants and other workers separately, while the building of the quantitative model was built following the participants' agreement on the subsystems' behaviors. Once this was completed for each subsystem, all subsystems became ready to be connected in a full model. The full model went through a number of changes until its behavior was accepted by all of the group members and also by some employees that worked in each of the subsystems.

The results related to the subsystems were compared to the results of the full model. Some of the most meaningful differences include: (a) The worsening of the

Pressure on Employees variable, which in the full model is impacted by more variables such as the *Corrective Maintenance Tasks* and the *Level of Interruptions*. (b) The *Problems and Malfunctions* variable and the rates it relied on are higher in the full model than in the Production subsystem model because of the additional feedback loops that these variables are connected to. (c) The *Corrective Maintenance Tasks* variable is lower in the full model than in the Maintenance subsystem model probably because of the connection with the *Quality Culture Level* variable which reduces the rate at which the corrective maintenance tasks accrue. These results are consistent with the behavior of the real enterprise. (d) The amount of the *Urgent Quality Tasks* variable in the full model is less than expected considering the behavior of this stock variable in the quality subsystem model. This reduction might be explained by the connection between the *Urgent Quality Tasks* variable to the *Quality Culture Level* variable. (e) The *Level of Interruptions* variable in inventory is impacted negatively by *Quality Culture Level* variable which causes a reduction in its values in the full model compared to its values in the corresponding inventory subsystem model. (f) *Personal Stress*'s results in the full model are more extreme than its results in the personal subsystem model. This is because the *Personal Stress* variable in the personal subsystem is not affected by the employees' pressure as it is in the full model, which causes it to increase to high levels in the full model (Table 4-1, p.268).

Policy alternatives which are essential to investigate as part of this research involved improving quality culture, workers' health and organizational effectiveness by understanding the relationships between these variables. As explained in Section 4.6 (p. 267), policy changes included: (a) adding *Top Management* variable as an essential part of *Quality Culture Level* with a random uniform value with a means of 0.8 and standard deviation of 0.1, (b) workers' motivation (*What Motivated Humans*) was changed to a random uniform value between 0.7 and 0.9, (c) learning (*Learning and Continuous Improvement*) was changed to a random uniform value between 0.7 and 0.9, (d) and *Relationship with Environment* was changed to a random uniform value between 0.6 and 0.8. Furthermore, the *Training* variable was changed to a stock (*Training Level*) with an inflow going out from the *Open Quality Tasks* stock.

<u>Model Variable</u>	<u>Present Behavior Results</u>	<u>Policy Alternative Simulation Results</u>	Reference Figure	Reference Page
Quality Culture Level	Exponential decay, with the 'goal-seeking' of 0.34	Exponential decay, with the 'goal-seeking' of 0.99	4-72	272
Training Level	An auxiliary variable, oscillating between 0-0.1	Exponential decay, with the 'goal-seeking' of 0.75	4-73	272
Perceived Job Control	Oscillates between 2.1-2.83 (questionnaire results)	Oscillates between 2.28-3.35 (*)	4-74	273
Personal Stress	Exponential decay, with the 'goal-seeking' of 625	Exponential decay, with the 'goal-seeking' of 580 (*)	4-75	273
Urgent Quality Tasks	Oscillates between 0.1-2.9	Oscillates between 0-2.1 (**)	4-76	274
Corrective Maintenance Tasks	Oscillates between 15-45 (most of the days, between 15-30)	Goal-seeking starting at 30 declining to almost zero (0.7-0.2)	4-77	274
Level of Interruptions	Oscillates between 0.25-0.7	Oscillates between 0.1-0.4	4-78	275
Correct Task Completion Rate	Oscillates between 1.25-4.5	Oscillates between 2-5.5	4-79	275
Problems and Malfunctions	Oscillates between 0.5-2.5	Oscillates between 0.1-1.5	4-80	276
Perceived Organizational Effectiveness	Oscillates between 0.125-0.8	Oscillates between 0.2-0.95	4-81	276
Organization Commitment	Oscillates between 0.2-0.8	Oscillates between 0.25-1.5	4-82	277

(*) Impacted by Quality Culture Level and Training Level

(**) With time, the average value diminishes and eventually the maximum value stabilizes between 1.9 -2.2

Table 5-1: Comparison of the Present Behavior Results with the Policy Alternative Simulation Results

The decision makers' suggestions for improvement particularly emphasized the notion of having more effective leadership (*Top Management*) which is considered essential for any organizational change and improvement. Other suggestions included improving *workers' training, motivation, relationship with the environment and organizational learning* all of which cause the *Quality Culture Level* and *Training Level* variables to increase. As expected, the high increase of the *Quality Culture Level* and *Training Levels* increase the *Perceived Job Control* which decreases *Personal Stress* and the *Urgent Quality Tasks Arrival Rate*. The later in turn causes the *Urgent Quality Tasks* to decrease, *CMT (Corrective Maintenance Tasks) Arrival Rate* to decrease, causing in turn the *Corrective Maintenance Tasks* and the *Level of Interruptions* to decrease. Subsequently, the *Correct Task Completion Rate* increases and the *Problems and Malfunctions* decreases, causing the increase of the *Organizational Effectiveness* and *Perceived Organizational Effectiveness* that in turn impacts the *Organization Commitment* to increase (Table 5-1). These changes in policy can bring about the required remedy to the firm's performance problems.

5.2 Conclusions

The crux of this research was to investigate the dynamic behavior associated with the interactions among quality culture, employees' health and organizational effectiveness in an organizational system. The dynamic hypotheses of this research evolved from various domains in the literature and therefore are representative of the mental models associated with different professional references. The task to address these dynamic hypotheses through a formal modeling process is a journey with an unknown end.

The motivation to implement the modeling process described by Sterman (2000) was based on the assumption that important linkages exist among these three concepts. By using the system dynamics approach it was believed that it would be feasible to gain insights associated with these hypotheses.

The initial dynamic hypotheses that were derived from the literature were the initial departure points for the modeling process but not necessarily its final goals since in many cases real systems do not behave exactly as the literature assumes.

First, I will remind the reader of the dynamic hypotheses that were obtained from the literature, which motivated me to carry out this research. Second, I will discuss the dynamic hypotheses that related to the interaction among quality culture, employees' health and organizational effectiveness which were developed through the system dynamics modeling process.

5.2.1 Examining the Relevant Dynamic Hypotheses from the Literature

“An essential feature of theory building is comparison of the emergent concepts, theory, or hypotheses with the extant literature. This involves asking what is this similar to, what does it contradict, and why. A key to this process is to consider a broad range of literature.” (Eisenhardt, 1989)

Reading the literature from various domains of knowledge such as engineering, psychology, management and other disciplines, divergent dynamic hypotheses that link quality culture, employees' health and organizational effectiveness were obtained (Beer, 1980; Forrester, 1993; Senge, 1990; Sudit, 1996; Mann, et al., 1994; Keating, et al., 1999; Oliva, et al., 1998; Purnendu, et al., 1998; Capra, 1983; Gryna, 2001; Riedel, et al., 2001; Berger, et al., 2001; Karasek, et al., 1990; Rosen, 1992; Jaffe, 1995; Browne, 2000; Sapolsky, 1994; Detert et al., 2000). The diverse literature led to the following dynamic hypotheses which are depicted in Figure 5-1.

5.2.1.1 Dynamic Hypothesis #1 (Double Loop Learning)

To become effective in an organization, the manager or worker needs to be involved in a learning process that influences his/her mental models so that she/ he can move to new ways of thinking which subsequently can lead to a greater acceptance of change and growth. Assuming that there is a desire for this kind of learning and openness, this may result in a gap between the current mental model one has and the new mental models one engages in. This gap may lead to decisions about the actions that one needs to take in order to experience life; and, in turn, this leads to more gained experience. More learning provides more tools and motivation to make one aware of the existing gap and hopefully to accept the new mental models (based on Forrester (1993) and Senge (1995)).

The group-model-building members in this research were mostly aware of problems concerning the firm itself and less aware of individual difficulties in the firm's environment. I assumed that (a) the group-model-building members were not aware of the notion of 'learning' and its dynamic behavior, and that (b) 'learning' is an essential source for the realization of a quality culture. Since the firm lacked a high level of quality culture the concept of learning and its dynamic behavior could not be addressed.

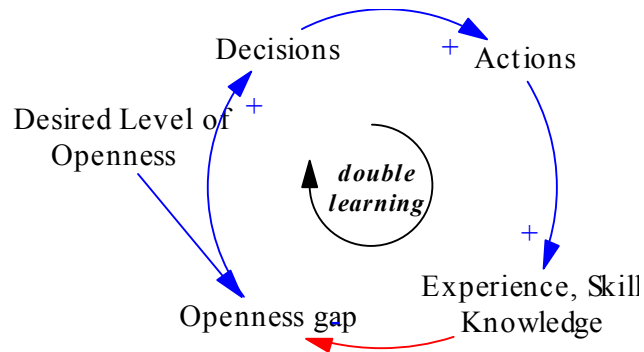


Figure 5-2: The Double Loop Learning Dynamic Hypothesis (1) as Represented in the Literature

5.2.1.2 Dynamic Hypothesis #2 (Stress/Control)

The more experience gained, through the development of one's skills and knowledge, the more control one has on his/her life. The greater the fit between the sense of control and the desire for control, the less stress is introduced in one's life and this fit subsequently encourages a person to look for more experience and more learning opportunities (based on Karasek et al., 1990; Rosen, 1992 and Sapolsky, 1994).

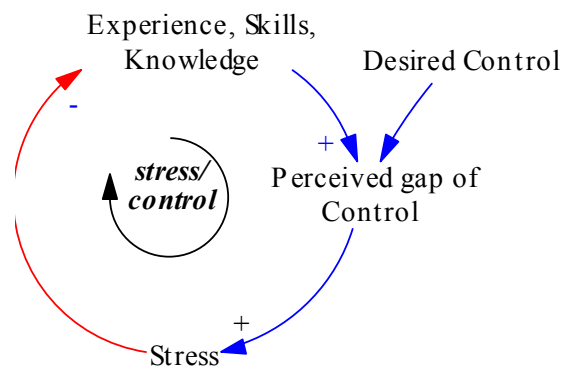


Figure 5-3: The Stress/Control Dynamic Hypothesis (2) as Represented in the Literature

Feedback loop R5, which is part of the personal subsystem, introduces this dynamic hypothesis: The higher the *Work Satisfaction*, *Social Environment*, and *Perceived Job Control*, the higher is the *Experience and Learning Rate*, causing the *Employees Satisfaction Level* to increase, which results in an increase in the *Stress Relief Rate*. When *Stress Relief Rate* increases, *Personal Stress* decreases; this in turn decreases the *Satisfaction Erosion Rate* and increases the *Employees Satisfaction Level* even more (Figure 5-4).

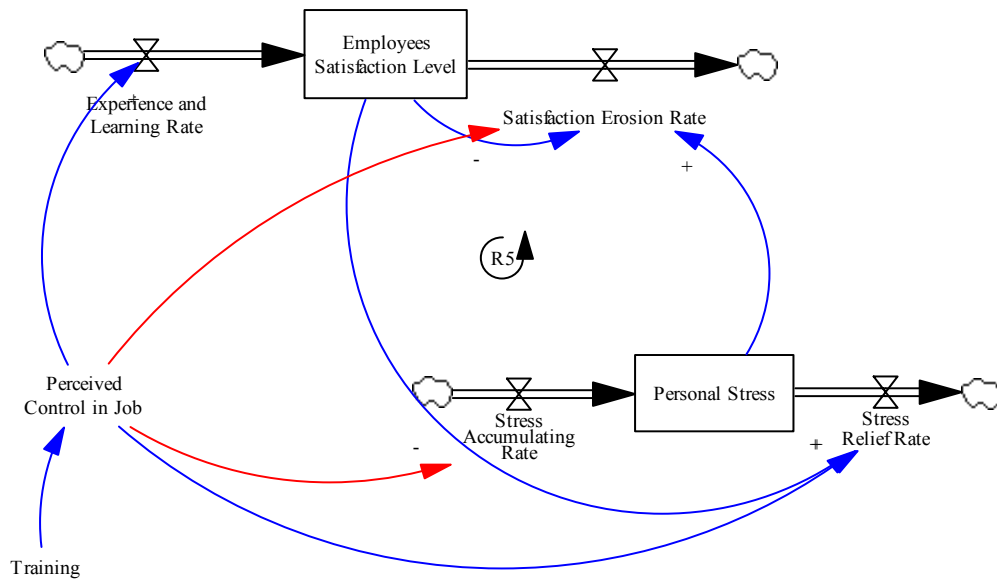


Figure 5-4: Dynamic Hypothesis # 2 as Represented in the Research Model

Perceived Job Control is an external variable to this feedback loop. As long as it increases it positively impacts the *Experience and Learning Rate*, and *Stress Relief Rate* causing the *Personal Stress* to decrease and *Employees Satisfaction Level* to increase. For the specific firm analyzed in this research, the *Perceived Job Control* is low, *Experience and Learning Rate*, and *Stress Relief Rate* are low causing the *Personal Stress* to be high and *Employees Satisfaction Level* to be low. During the policy analysis phase described in Section 4.6 (p. 267), *Perceived Job Control* was increased causing the decrease of *Personal Stress*. However, this increase did not impact the *Employees Satisfaction Level*. Overall, this dynamic hypothesis has been demonstrated by the actual structure of the model built by the group's participants, and the results of the policy alternative simulation of this research. The limitations of this dynamic hypothesis stem from the use of a

questionnaire for the values of the *Experience and Learning Rate* variable and the *Satisfaction Erosion Rate* variable, therefore there is a little impact from the changes within the loop these variables are connected to.

5.2.1.3 Dynamic Hypothesis #3 (Job Satisfaction/Health)

The more experience, skills and knowledge gained, the more job satisfaction one feels, as long as the perception of the level of collaboration, the level of decision latitude, and the level of participation and the involvement are close to the levels one desires. The closer the level of job satisfaction is to the desired level of job satisfaction, the more one feels pleased. Subsequently this pleasure influences positively one’s state of health. If an employee experiences a higher level of health status, he/she tends to be less absent and more productive at work, which provides her/him with a greater opportunity to take more actions and develop more skills and knowledge (based on Karasek et al., 1990; Oliva et al., 1998; Berger et al., 2001; Riedel et al., 2001; Ho, 1997).

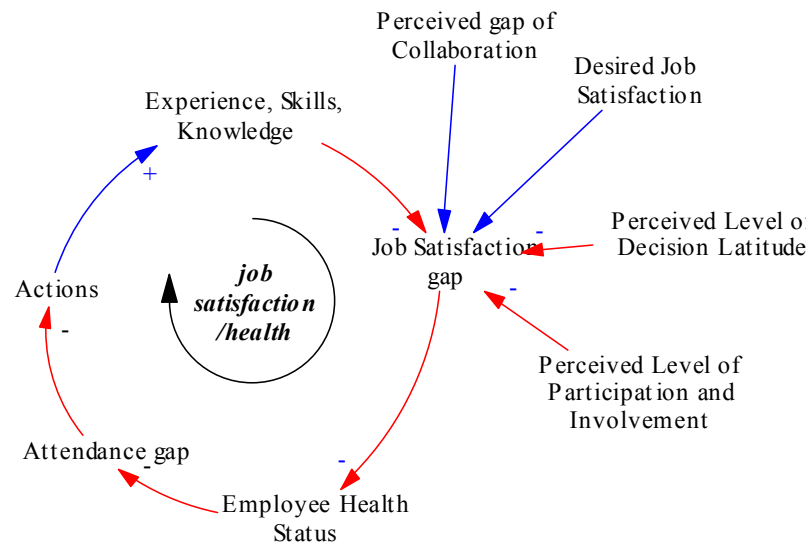


Figure 5-5: The Job Satisfaction/Health Dynamic Hypothesis (3) as Represented in the Literature

This dynamic hypothesis is realized very closely to the feedback loops of the model. In the process of building the first stock and flow diagram (Appendix G), this dynamic hypothesis has been included as depicted in Figure 5-6. According to the group participants, the inflow rate to the *Employees Satisfaction Level* is the *Experience and Learning Rate*, which increases when *Time devoted for Experience and Learning* increases (loop R10). It is impacted by the *Personal Stress*. Stress as a health problem

requires the need for relief, therefore absenteeism occurs and consequently personal stress decreases. With less stress, an employee is able to devote more time to experience and learning, thus increasing his satisfaction. In the literature and the subsequent dynamic hypothesis described in Chapter 2, absenteeism is the effect of the health condition of the employee which is impacted by his level of satisfaction (Rosen, 1995; Ho, 1997; Karasek et al., 1990; Sapolsky, 1994).

The perception of level of collaboration, level of decision latitude, and level of participation and involvement were not considered as conditions for employee satisfaction. These variables are mainly dimensions of the quality culture variable and the group members were not familiar with them enough to consider them as conditions for work satisfaction.

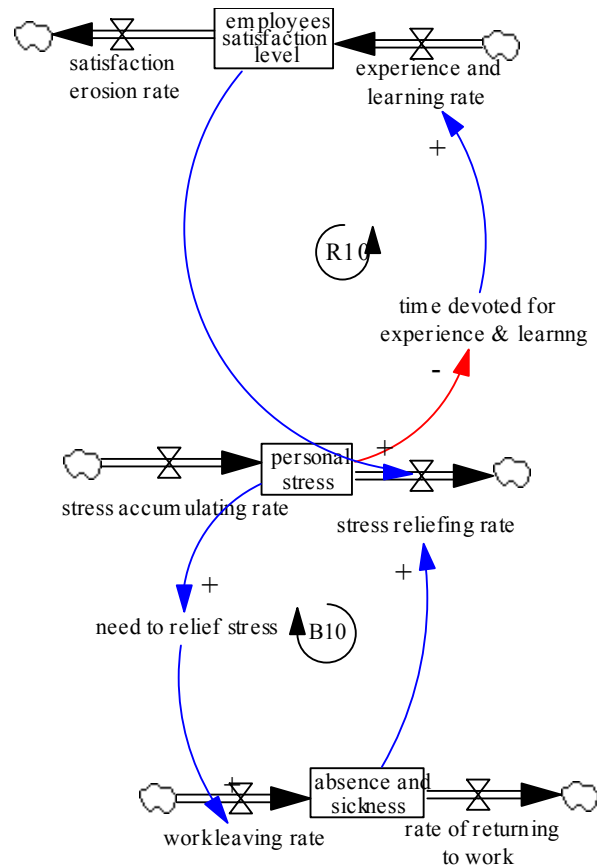


Figure 5-6: Dynamic Hypothesis # 3 in the First Stock and Flow Diagram

At the end of the model building process, this dynamic hypothesis appears as depicted in Figure 5-7. According to this figure, when *Quality Culture Level* is high,

Perceived Job Control increases, increasing *Experience and Learning Rate* so that *Employees Satisfaction Level* increases and *Stress Relief Rate* increases too. Subsequently *Personal Stress* decreases and therefore less sickness occurs which increases *Correct Task Completion Rate*. *Quality Culture Level* includes the perception of level of collaboration, the level of decision latitude, and the level of participation and involvement (Figure 4-43, p.239).

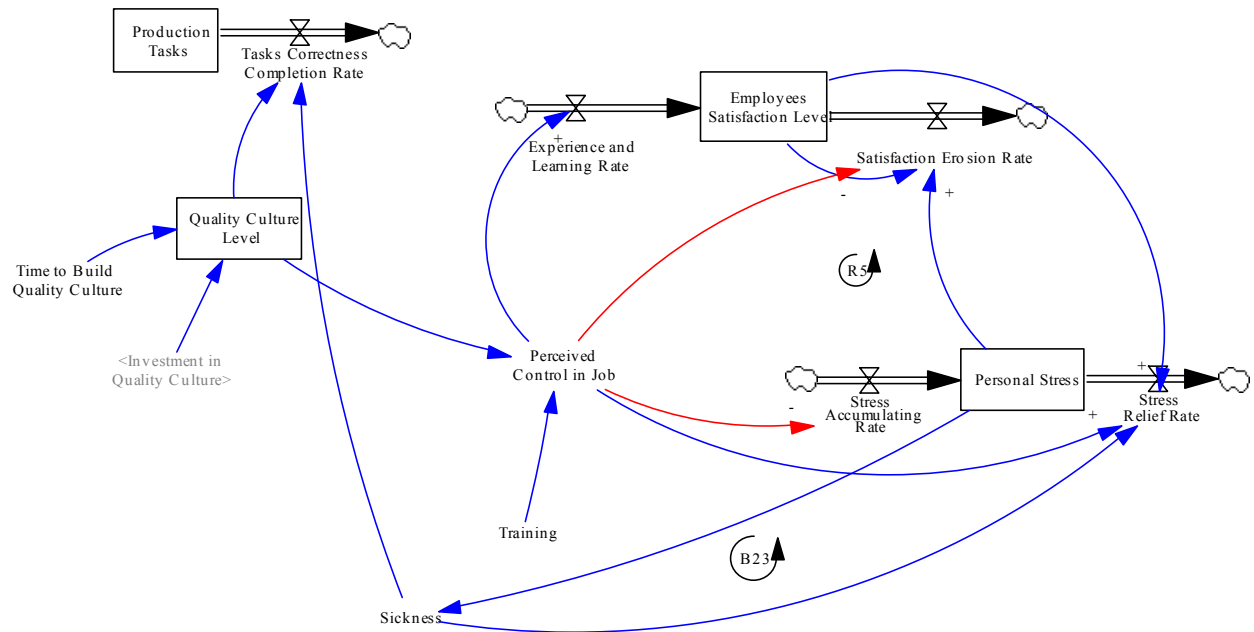


Figure 5-7: Dynamic Hypothesis # 3 as Represented in the Research Model

With respect to this dynamic hypothesis and dynamic hypothesis #2, my conclusion is that the research process demonstrated these two hypotheses together, while the version of dynamic hypothesis obtained from the literature according to my concept, were articulated separately.

5.2.1.4 Dynamic Hypothesis #4 (Stress Recovery)

The perceived lack of knowledge and skills, and therefore lack of control causes stress to build up. If this is accompanied with low decision latitude, then stress accumulates even more. When stress builds up, a person experiences a distancing from his desired comfort zone. If he feels stressed, the greater the chances he will get sick

providing him/her with an escape route to lower his/her stress (based on Karasek et al., 1990 and Capra, 1983).

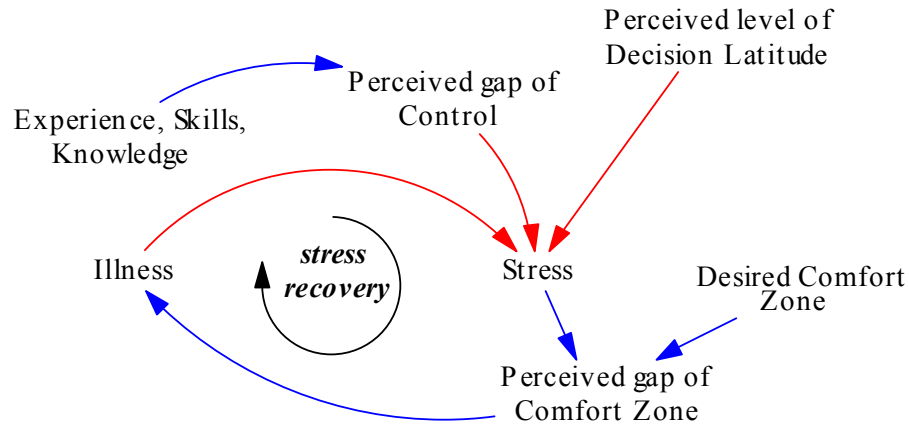


Figure 5-8: The Stress Recovery Dynamic Hypothesis (4) as Represented in the Literature

This dynamic hypothesis deals with the linkage among stress and illness. Stress at work according to Karasek et al., results from lack of control and decision latitude. Such deficiency reinforces personal stress. Evidently, the more stress, the more one feels uncomfortable, probably causing more illness - another means of escaping stress.

The model depicts this dynamic hypothesis in the following relationships which are part of loop B23 (Figure 5-9): *Training* and *Quality Culture Level* positively influence the *Perceived Job Control* i.e., the more they increase the more *Perceived Job Control* increases. The *Perceived Job Control* impacts the inflow and outflow rates of *Employees Satisfaction Level* and *Personal Stress* variables. The higher the perceived lack of knowledge and skills and the lack of control are, the more the *Perceived Job Control* decreases the outflow rate of the *Employees Satisfaction Level* and the inflow rate of the *Personal Stress* variables and increases the inflow of the *Employees Satisfaction Level* and the outflow rate of *Personal Stress*. When *Personal Stress* increases it increases sickness, causing the *Stress Relief Rate* to increase, decreasing *Personal Stress* (loop B23). We can conclude that this dynamic hypothesis has been demonstrated in this research.

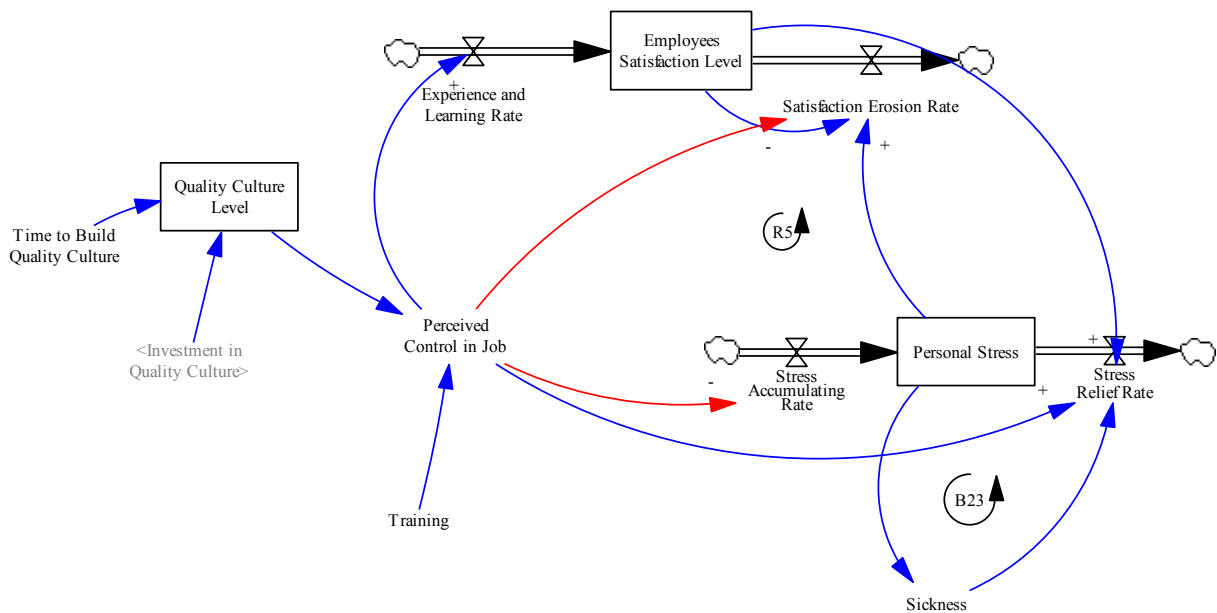


Figure 5-9: Dynamic Hypothesis # 4 as Represented in the Research Model

5.2.1.5 Dynamic Hypothesis #5 (Absenteeism/Stress)

Illness obviously is a frequent cause for absenteeism, subsequently causing the person to be less productive and less able to be involved in a learning process (acquiring fewer skills and less knowledge), which in turn causes even more stress to build up and eventually more illness (based on Karasek et al., 1990; Berger et al., 2001; Riedel et al., 2001; Sapolsky, 1994; Capra, 1983).

This dynamic hypothesis deals with the individual person in a firm. Sickness limits one's ability to learn and to improve skills and knowledge. It positively impacts personal stress. With the feeling of more stress one tends to succumb to more sickness (Figure 5-10).

The relationship between stress and absenteeism was accepted by the group, as depicted in the model in loop B23 (Figure 5-9). As mentioned in Section 4.3.2.5 (p. 199), the firm's employees receive a bonus if they are not absent from work. The workers are seldom absent. The premise that appears in the conceptual model that when employees are stressed, they choose to take a leave of absence as being sick is included in the model, but with values that have a little impact on the model; therefore the impact of absenteeism on workers' stress is not included in the research model.

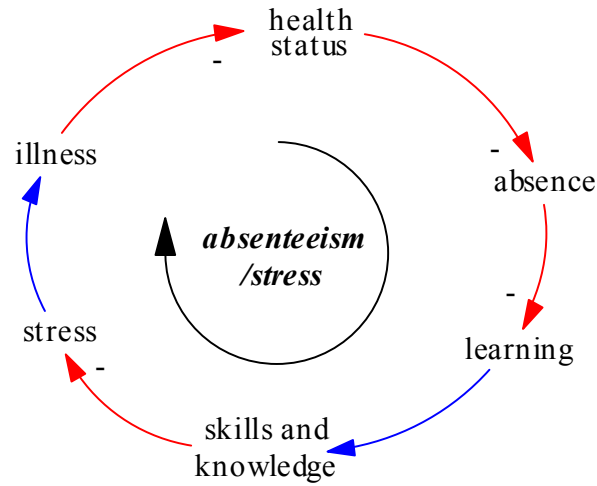


Figure 5-10: The Absenteeism/Stress Dynamic Hypothesis (5) as Represented in the Literature

5.2.1.6 Dynamic Hypothesis #6 (Motivation)

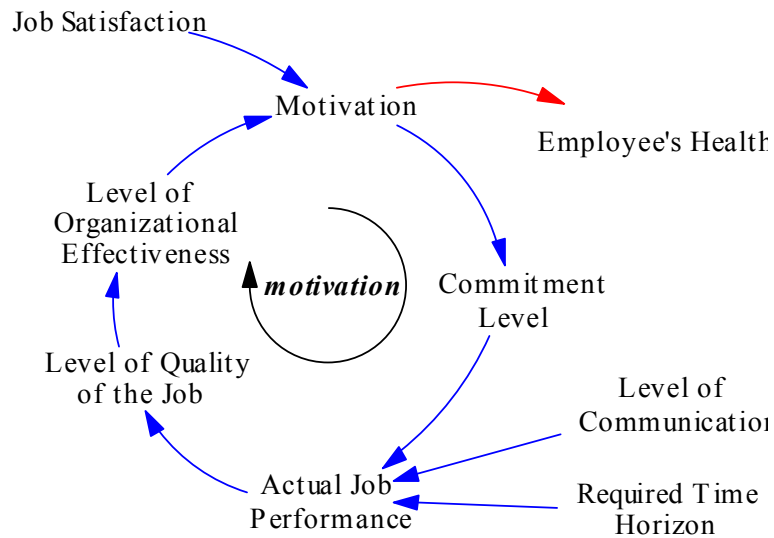


Figure 5-11: The Motivation Dynamic Hypothesis (6) as Represented in the Literature

The greater the job satisfaction one experiences, the more motivation she/he has to work. When motivation is high, the commitment level is also high, which positively influences job performance. This will hold true as long as the level of communication needs is commensurate with the reward received and as long as time horizons

considerations are adequate with those required for completing the job. If the actual (as opposed to desired) level of job performance is high, the level of the quality of the job is high, resulting in a higher level of both employee and organizational effectiveness. When organizational effectiveness rises, so does the level of employee motivation, which is a positive influence on an employee's health (based on Keating et al., 1999; Karasek et al., 1990; Purnendu et al., 1998; Jaffe, 1995; Browne, 2002; Beer, 1980; Rosen, 1992).

This dynamic hypothesis deals with the relationships between satisfaction, motivation and commitment and how they all affect organizational effectiveness. A very similar dynamic hypothesis appears in the research model as loop R6 (Figure 5-12):

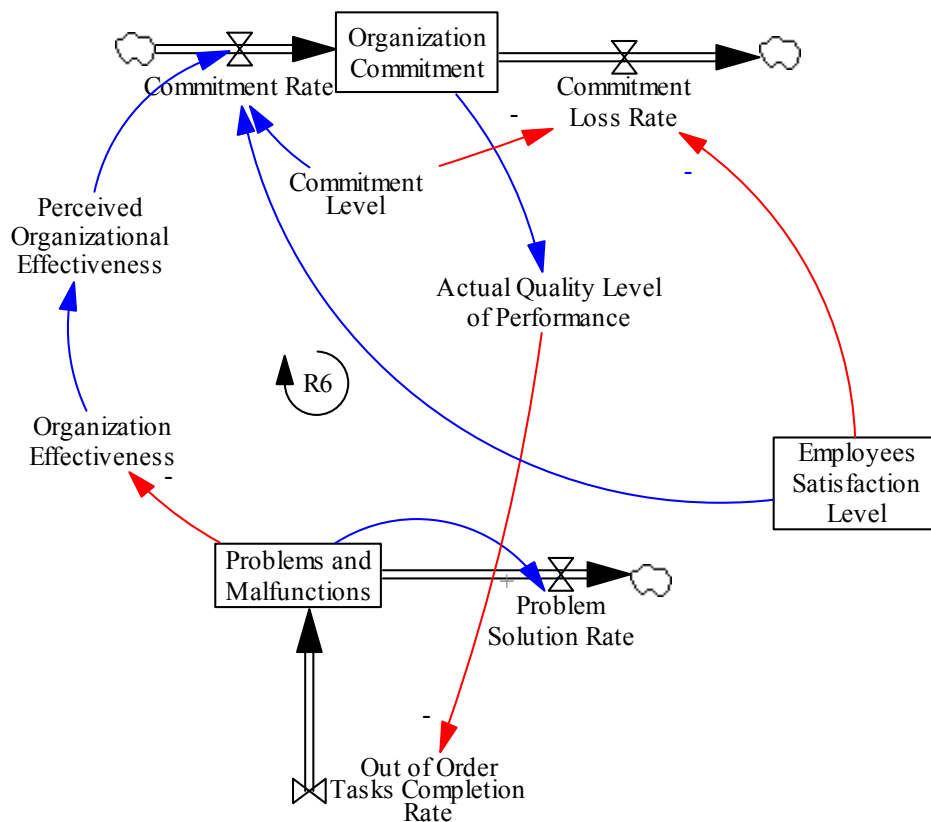


Figure 5-12: Dynamic Hypothesis # 6 as Represented in the Research Model

The differences between loop R6 of the research model and the dynamic hypothesis based on the literature are as follows: (a) the group model building members dealt with commitment only (not including motivation), (b) the level of quality of jobs was considered to have a negative impact on the *Out of Order Tasks Completion Rate*, meaning that a decrease in this rate causes fewer *Problems and Malfunctions* to occur,

resulting in higher level of *Organization Effectiveness*. We can conclude that this dynamic hypothesis has been included in the research and the confirmation of the literature is achieved. This dynamic hypothesis also demonstrates the linkage between quality level of jobs and organizational effectiveness, and the linkage between personal feelings like satisfaction and commitment to organizational effectiveness.

5.2.1.7 Dynamic Hypothesis #7 (Collaboration Trap)

The larger the gap between the current mental model one possesses and the new mental models one engages in ('openness gap'), the greater the need for collaboration, which increases the perceived gap of the level of collaboration, and also the gap between old and new mental models (based on Forrester, 1993; Gryna,2001 and Detert et al., 2000).

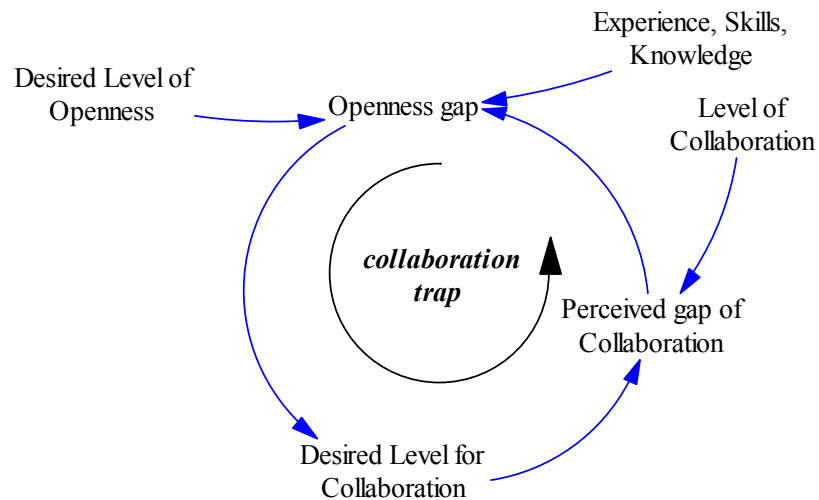


Figure 5-13: The Collaboration Trap Dynamic Hypothesis (7) as Represented in the Literature

This dynamic hypothesis deals with the issue of the gap in terms of mental models which are almost impossible to define meaningfully. Mental models are changed only in terms of the degree of collaboration. Collaboration has not been included in the model in its first version. Collaboration was brought up only after I questioned the group members about the dimensions of quality culture which they had to measure (Figure 4-43, p. 239 and Appendix O). The notion of mental models gap could not be demonstrated in this research. I assume that in order to measure mental models, some other kinds of knowledge and professional tools are needed.

5.2.1.8 Dynamic Hypothesis #8 (Health/Quality)

The level of quality culture increases with more managerial practices like collaboration, provision of decision latitude, participation and involvement, and with more communication and long-term plans. The level of quality culture decreases when there is less openness in the organization. As quality culture increases, organizational effectiveness increases, which subsequently influences employee motivation. An increase in employee motivation also causes an increase in employee’s health status which lowers the absenteeism rate and improves the learning ability of the worker thus decreasing the openness gap and increasing the level of quality culture (based on Detert et al., 2000; Jaffe, 1995; Browne, 2002; Beer, 1980; Rosen, 1992; Sudit, 1996; Mann, et al., 1994; Ho, 1997).

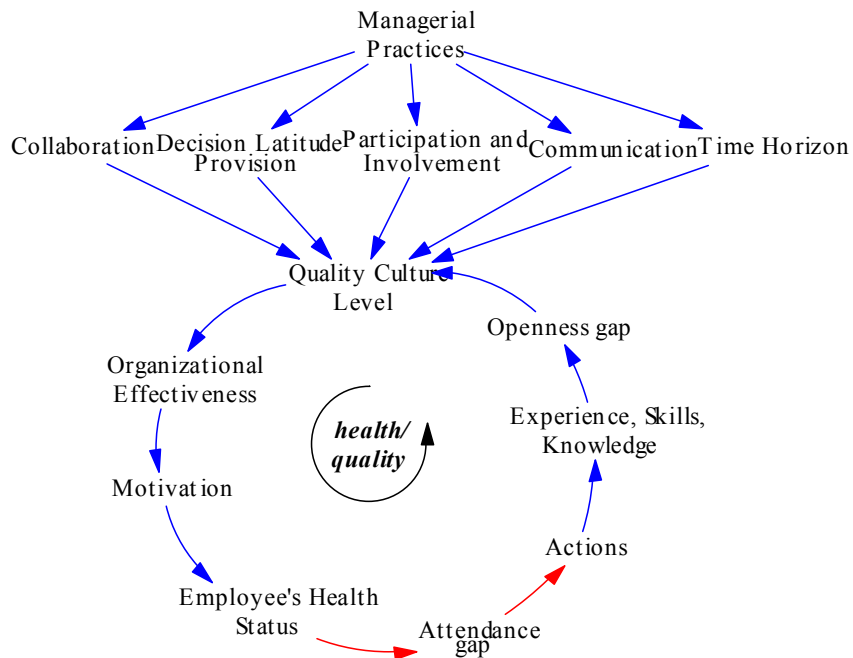


Figure 5-14: The Health/Quality Dynamic Hypothesis (8) as Represented in the Literature

This dynamic hypothesis deals with the dimensions of quality culture, i.e., collaboration, provision of decision latitude, participation and involvement, communication and the long-term plans. These are also the main dimensions of the quality culture in the model (Figure 4-43, p. 239). As quality culture increases, organizational effectiveness increases. An improvement of organizational effectiveness

impacts employees' motivation and health status positively, which causes the workers to be less absent. Being more involved at work enables the workers to learn more and improve their experience, skills and knowledge, thus decreasing their openness gap and increasing quality culture even more. The openness gap of the individual means the gap between the old mental models and the new ones. As explained in Section 5.2.1.7 (p. 294), the notion of mental models gap could not be demonstrated in this research. This dynamic hypothesis appears in the research model as depicted in Figure 5-15. In the model, *Quality Culture Level* is affected by the level of the *Relationship with the Environment*, *the Degree of Shared Control and Collaboration*, *the Balance between Production and Social Activities*, *Learning and Continuous Improvement*, *What Motivates Humans*, *Time Horizon* and *the Management by Fact* (Figure 4-43, p.239). These dimensions are very similar to the dimensions in the dynamic hypothesis which was obtained from the literature (Detert et al., 2000). They all increase quality culture when they increase themselves. As *Quality Culture Level* increases, it causes *Correct Task Completion Rate* to increase, and causing *Out of Order Tasks Completion Rate* to decrease. As a result, the *Problems and Malfunctions* stock decreases. Subsequently, *Organization Effectiveness* increases, causing the *Organization Commitment* to increase. The end of this dynamic hypothesis was not included in the research, meaning that the impact of higher level of motivation or commitment on the health status or on personal stress has not been demonstrated.

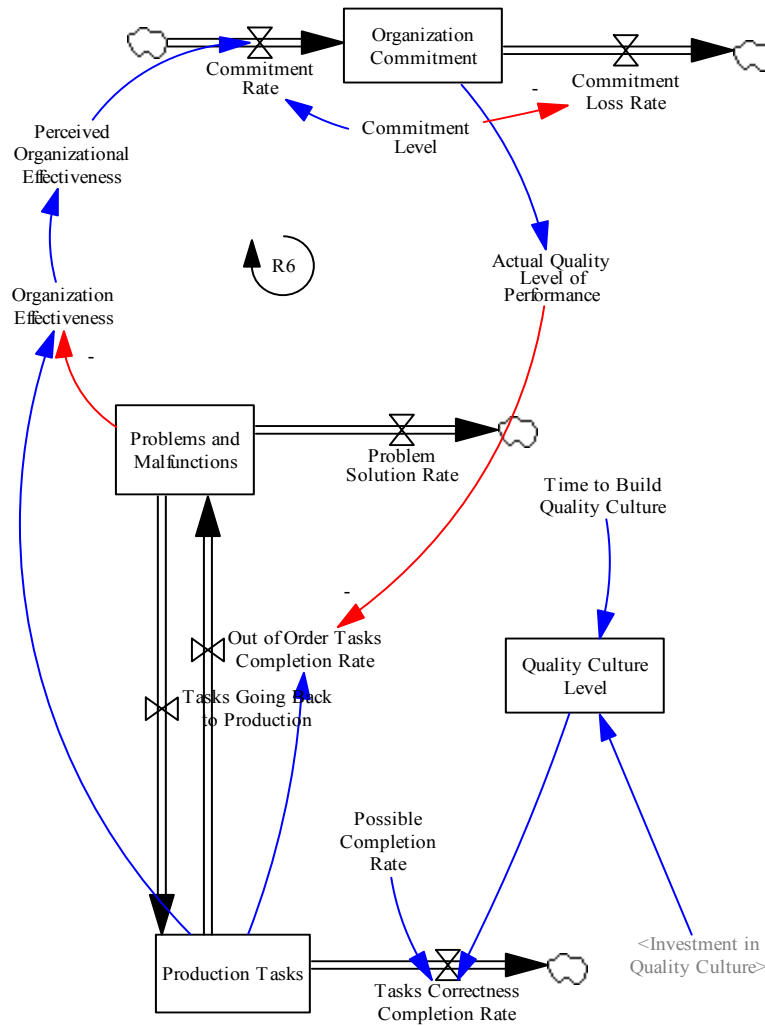


Figure 5-15: Dynamic Hypothesis # 8 as Represented in the Research Model

“While linking results to the literature is important in most research, it is particularly crucial in theory-building research because the findings often rest on a very limited number of cases.” (Eisenhardt, 1989, p. 545)

The comparison of the literature dynamic hypotheses and the research dynamic hypotheses is summarized in Table 5-2:

Dynamic Hypothesis	As Represented in the Literature	Conclusions
(1) Double Loop Learning	To become effective in an organization, the manager or worker needs to be involved in a learning process that influences his/her mental models so that she/ he can move to new ways of thinking which subsequently can lead to a greater acceptance of change and growth. Assuming that there is a desire for this kind of learning and openness, this may result in a gap between the current mental model one has and the new mental models one engages in. This gap may lead to decisions about the actions that one needs to take in order to experience life; and, in turn, this leads to more gained experience. More learning provides more tools and motivation to make one aware of the existing gap and hopefully to accept the new mental models (based on Forrester (1993) and Senge (1995)).	(a) the group-model-building members were not aware of the notion of 'learning' and its dynamic behavior, and that (b) 'learning' is an essential source for the realization of a quality culture. Since the firm lacked a high level of quality culture the concept of learning and its dynamic behavior could not be addressed.
(2) Stress/ Control	The more experience gained, through the development of one's skills and knowledge, the more control one has on his/her life. The greater the fit between the sense of control and the desire for control, the less stress is introduced in one's life and this fit subsequently encourages a person to look for more experience and more learning opportunities (based on Karasek et al., 1990; Rosen, 1992 and Sapolsky, 1994).	This dynamic hypothesis has been demonstrated by the actual structure of the model built by the group's participants, and the results of the policy alternative simulation of this research. The limitations of this dynamic hypothesis stem from the use of a questionnaire for the values of the <i>Experience and Learning Rate</i> variable and the <i>Satisfaction Erosion Rate</i> variable, therefore there is a little impact from the changes within the loop these variables are connected to.

Dynamic Hypothesis	As Represented in the Literature	Conclusions
(3) Job Satisfaction/ Health	<p>The more experience, skills and knowledge gained, the more job satisfaction one feels, as long as the perception of the level of collaboration, the level of decision latitude, and the level of participation and the involvement are close to the levels one desires. The closer the level of job satisfaction is to the desired level of job satisfaction, the more one feels pleased. Subsequently this pleasure influences positively one's state of health. If an employee experiences a higher level of health status, he/she tends to be less absent and more productive at work, which provides her/him with a greater opportunity to take more actions and develop more skills and knowledge (based on Karasek et al., 1990; Oliva et al., 1998; Berger et al., 2001; Riedel et al., 2001; Ho, 1997).</p>	<p>This dynamic hypothesis is realized very closely to the feedback loops of the model. In the process of building the first stock and flow diagram this dynamic hypothesis has been included as depicted in Figure 5-6.</p> <p>The perception of level of collaboration, level of decision latitude, and level of participation and involvement were not considered as conditions for employee satisfaction. These variables are mainly dimensions of the quality culture variable and the group members were not familiar with them enough to consider them as conditions for work satisfaction.</p>
(4) Stress Recovery	<p>The perceived lack of knowledge and skills, and therefore lack of control causes stress to build up. If this is accompanied with low decision latitude, then stress accumulates even more. When stress builds up, a person experiences a distancing from his desired comfort zone. If he feels stressed, the greater the chances he will get sick providing him/her with an escape route to lower his/her stress (based on Karasek et al., 1990 and Capra, 1983).</p>	<p>This dynamic hypothesis has been demonstrated in this research</p>

Dynamic Hypothesis	As Represented in the Literature	Conclusions
(5) Absenteeism/ Stress	Illness obviously is a frequent cause for absenteeism, subsequently causing the person to be less productive and less able to be involved in a learning process (acquiring fewer skills and less knowledge), which in turn causes even more stress to build up and eventually more illness (based on Karasek et al., 1990; Berger et al., 2001; Riedel et al., 2001; Sapolsky, 1994; Capra, 1983).	The relationship between stress and absenteeism was accepted by the group. The firm's employees receive a bonus if they are not absent from work. The workers are seldom absent. The premise that appears in the conceptual model that when employees are stressed, they choose to take a leave of absence as being sick is included in the model, but with values that have a little impact on the model; therefore the impact of absenteeism on workers' stress is not included in the research model.
(6) Motivation	The greater the job satisfaction one experiences, the more motivation she/he has to work. When motivation is high, the commitment level is also high, which positively influences job performance. This will hold true as long as the level of communication needs is commensurate with the reward received and as long as time horizons considerations are adequate with those required for completing the job. If the actual (as opposed to desired) level of job performance is high, the level of the quality of the job is high, resulting in a higher level of both employee and organizational effectiveness. When organizational effectiveness rises, so does the level of employee motivation, which is a positive influence on an employee's health (based on Keating et al., 1999; Karasek et al., 1990; Purnendu et al., 1998; Jaffe, 1995; Browne, 2002; Beer, 1980; Rosen, 1992).	The differences between the research model and the dynamic hypothesis based on the literature are as follows: (a) the group model building members dealt with commitment only (not including motivation), (b) the level of quality of jobs was considered to have a negative impact on the <i>Problems and Malfunctions</i> , resulting in higher level of <i>Organization Effectiveness</i> . This dynamic hypothesis has been confirmed in the research.

Dynamic Hypothesis	As Represented in the Literature	Conclusions
(7) Collaboration Trap	The larger the gap between the current mental model one possesses and the new mental models one engages in ('openness gap'), the greater the need for collaboration, which increases the perceived gap of the level of collaboration, and also the gap between old and new mental models (based on Forrester, 1993; Gryna,2001 and Detert et al., 2000).	Mental models are changed only in terms of the degree of collaboration. Collaboration has not been included in the model in its first version. Collaboration was brought up only after I questioned the group members about the dimensions of quality culture which they had to measure (Figure 4-43, p. 239). The notion of mental models gap could not be demonstrated in this research.
(8) Health/Quality	The level of quality culture increases with more managerial practices like collaboration, provision of decision latitude, participation and involvement, and with more communication and long-term plans. The level of quality culture decreases when there is less openness in the organization. As quality culture increases, organizational effectiveness increases, which subsequently influences employee motivation. An increase in employee motivation also causes an increase in employee's health status which lowers the absenteeism rate and improves the learning ability of the worker thus decreasing the openness gap and increasing the level of quality culture (based on Detert et al., 2000; Jaffe, 1995; Browne, 2002; Beer, 1980; Rosen, 1992; Sudit, 1996; Mann, et al., 1994; Ho, 1997).	This dynamic hypothesis deals with the dimensions of quality culture, i.e., collaboration, provision of decision latitude, participation and involvement, communication and the long-term plans. These are also the main dimensions of the quality culture in the model (Figure 4-43, p. 239). As quality culture increases, organizational effectiveness increases. An improvement of organizational effectiveness impacts employees' motivation and health status positively. The impact of higher level of motivation or commitment on the health status or on personal stress has not been demonstrated.

Table 5-2: The Dynamic Hypotheses as Presented in the Literature and the Conclusions from the Research

5.2.2 Research Questions and Research Findings

The present needs for organizations to be competitive, flexible (ready to make changes in order to survive), requires management to become ‘system thinkers’ (Senge et al., 1994). Moreover, the lack of research and studies regarding the interaction between quality culture, employees’ health and organization’s effectiveness was the reason for this undertaking. The interactions between quality culture and organization’s effectiveness were studied in the engineering school of thought (Sudit, 1996; Mann, et al., 1994; Keating, et al., 1999; Oliva, et al., 1998; Purnendu, et al., 1998; Gryna, 2001; Westbrook, et al., 1995; Saad, et al., 2000; Gore, 1999), where the basic premise is that improved organizational quality will eventually improve organizational effectiveness. The interaction between employee’s health and organization’s effectiveness is considerably a new concept of the organization’s psychology, where the basic premise is that employees’ health is an obligatory condition for the organization in order to be productive (Riedel, et al., 2001; Berger, et al., 2001; Allen, et al., 1999). The recognition of the interaction between quality culture and employee’s health was studied only recently in others (Beer, 1980; Schein, 1996; Karasek, et al., 1990; Rosen, 1992; Jaffe, 1995; Browne, 2002). Rosen, Karasek et al. and Jaffe recognize that the first attempt to improve employee’s health is to eliminate the effects of environmental stressors, which in turn affect positively quality initiatives through collective efforts, participation, motivation and learning. The literature could not provide the dynamic relationships among these three variables and therefore my impetus was to build dynamic hypotheses based on the literature and to research their existence in reality.

Reading and learning from literature builds our curiosity to find out what the basic premises and assumptions are. However, it does not mean that we will necessarily find that these premises and assumptions are valid. The questions that led this research dealt with the interaction between these three variables: quality culture, employees’ health and organization’s effectiveness. The research question was formulated as follows:

How can quality culture influence employees’ health and in turn be influenced by the culture in an organization? How does the interaction between quality culture and

employees' health influence organizational effectiveness and how is this interaction affected in turn by organizational effectiveness?

This research question was divided into sub-questions:

- 1) *In what ways do quality culture and employees' health interact and mutually influence each other?*
- 2) *How does the interaction between the quality system and employees' health interact and mutually influence organizational effectiveness?*

The modeling results provided in Chapter Four demonstrated the existence of a linkage between these three dimensions. An important finding of this research is the impact quality culture has on the level of organizational effectiveness and its impact on employees' health. However, the impacts of organizational effectiveness and employees' health on quality culture were not demonstrated.

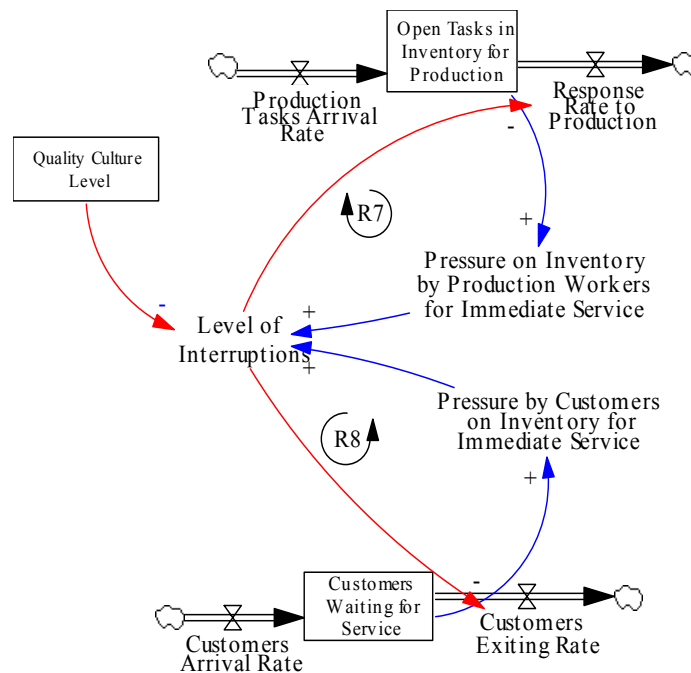


Figure 5-16: Quality Culture Level Impacts in the Inventory Subsystem

Quality culture impacts the behavior of all subsystems: In the Inventory subsystem quality culture affects the *Level of Interruptions*. *Level of Interruptions* is linked to two reinforcing loops, i.e., R7 and R8 (Figure 5-16). When *Open Inventory*

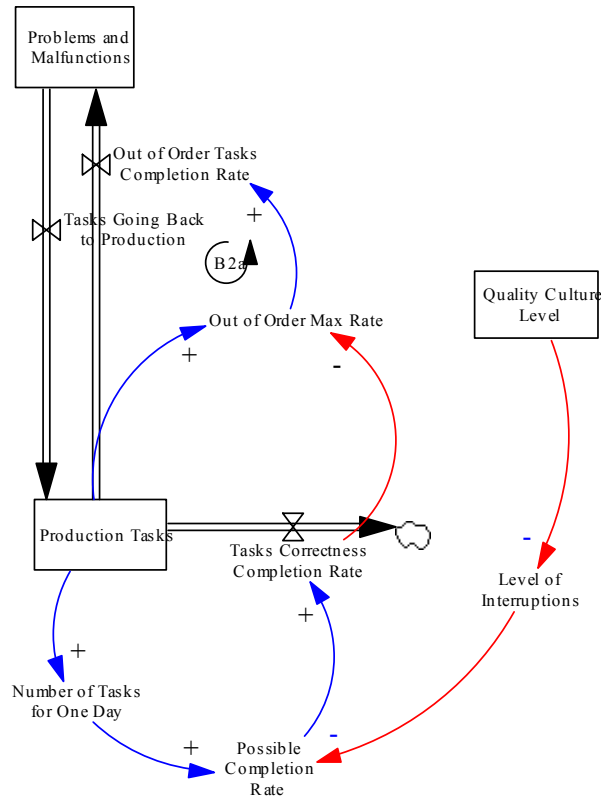


Figure 5-18: Quality Culture Level Impacts in the Production Subsystem – II

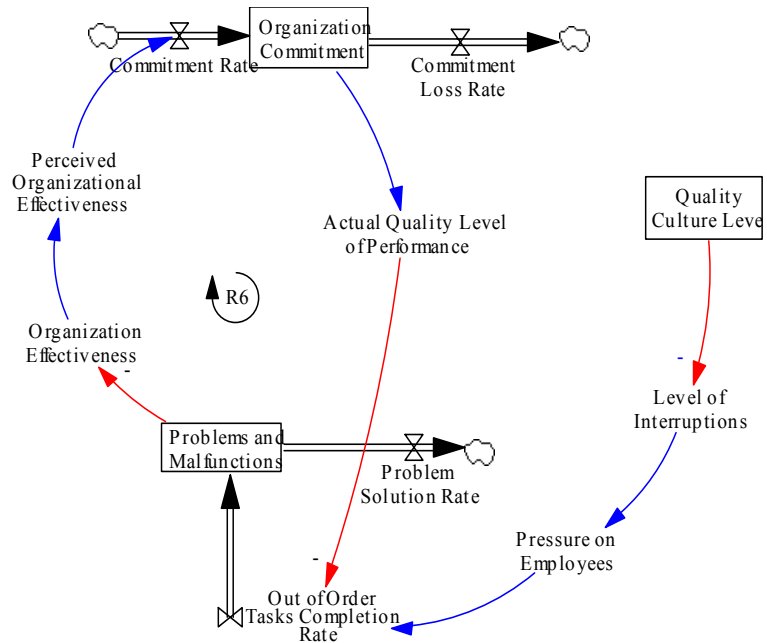


Figure 5-19: Quality Culture Level Impacts in the Personal Subsystem – I

Changes to the *Problems and Malfunctions* stock in Production Subsystem, which are the result of changes in the *Level of Interruptions*, affect the Personal Subsystem. When *Problems and Malfunctions* stock increases, *Organization Effectiveness* and *Organization Commitment* decrease (Figure 5-19).

Pressure on Employees which was impacted by the *Level of Interruptions* has a positive impact on the *Stress Level*. When *Pressure on Employees* increases, the *Stress Level* increases as well causing *Stress Accumulation Rate* and *Personal Stress* to increase. It leads to the R5- reinforcing loop which describes the relationships between *Employees Satisfaction Level* and *Personal Stress*: when *Personal Stress* increases, *Satisfaction Erosion Rate* increases, causing the *Employees Satisfaction Level* to decrease, which causes the *Stress Relief Rate* to decrease and the *Personal Stress* to increase even more (Figure 5-20).

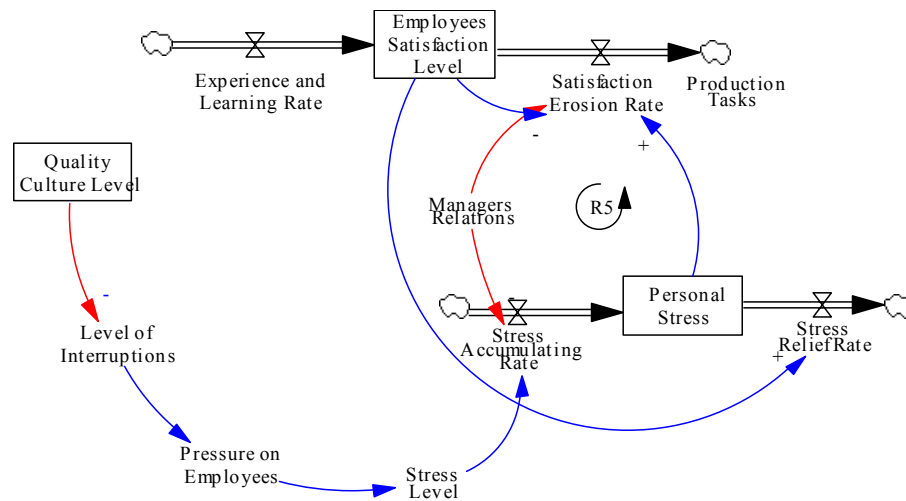


Figure 5-20: Quality Culture Level Impacts in the Personal Subsystem – II

The impact of *Quality Culture Level* reduces the *Level of Interruptions* (which is part of the Inventory subsystem) which in turn impacts the Personal and the Production subsystems, demonstrating the significance of the quality culture in the workplace when considering the employees' health and the organization's effectiveness.

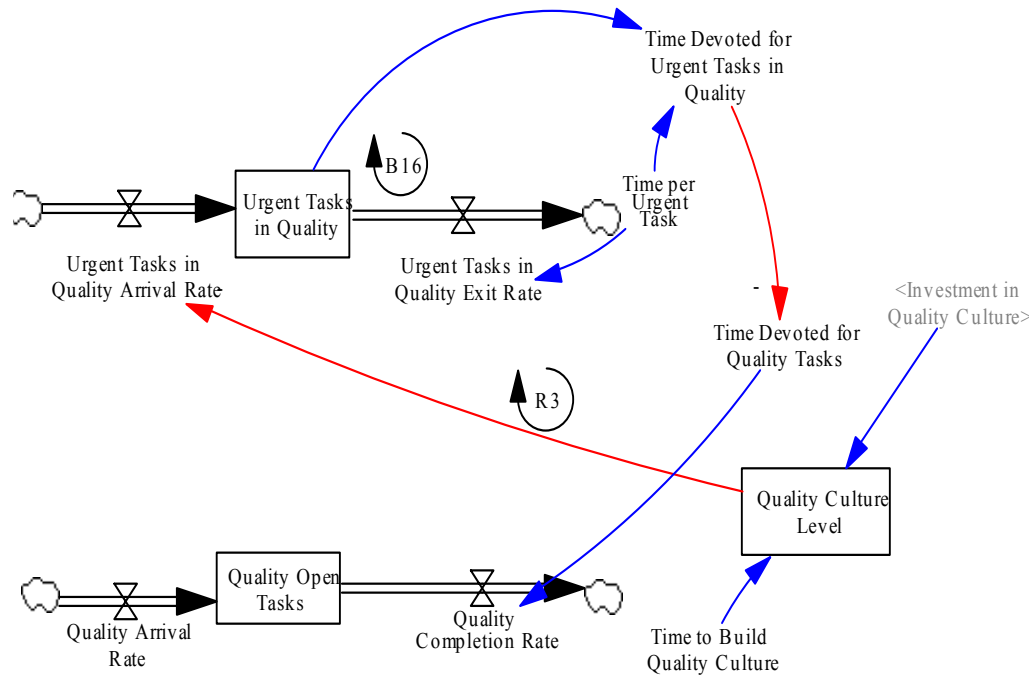


Figure 5-22: Quality Culture Level Impacts in the Quality Subsystem

Furthermore, the Production subsystem is influenced by the increase of the *Possible Completion Rate* and the *Correct Task Completion Rate* causing the *Out of Order Tasks Completion Rate* to decrease, thus decreasing the *Problems and Malfunctions* stock. As mentioned earlier, the Personal subsystem is also influenced because the *Problems and Malfunctions* stock decreases the *Organization Effectiveness* and the *Organization Commitment* (Figure 5-19).

Quality culture directly impacts the Personal subsystem through *Perceived Job Control* and the Production subsystem through *Correct Task Completion Rate*.

The conclusion from analyzing the dynamic hypotheses of this model is that quality culture has a great impact on the whole system, especially on employees' health and on organizational effectiveness. Furthermore, employees' health and organizational effectiveness mutually impact each other. This research did not demonstrate the impact of employees' health and organizational effectiveness on quality culture.

5.2.3 The Group Modeling Process

Building the model in this research was designed and developed mostly according to Vennix, (1996), Wolstenholme, (1999) and Richardson et al., (1995). In the following section, I will review details about building the model drawing from Vennix (1996) and others guidelines. I will also review additional elements that I used and will explain what can be learned from my own experience on how to improve the group modeling process.

Vennix's process of group model-building includes four stages. During the first stage the modeler/researcher has to decide whether to use qualitative or quantitative model. Regardless of the goals and the resources required for developing the model, Vennix argues that the use of a qualitative or quantitative model depends on the participants' inclination. If they tend to be analytical thinkers they should use a qualitative approach, and if they lack the ability required for analytical thinking then a formalized model is preferable. In this research, the participants lacked the ability required for analytical thinking. In addition, I chose the quantitative model, knowing from the outset that the results obtained from the quantitative model will be the focus of my research. My conclusion from this experience is that whether the audience involved in the modeling effort is more analytical or not, the decision to use a quantitative model depends mainly on the ultimate goal of the modeling effort rather than on the inclination of the audience.

During the second stage one has to decide how many participants should be involved in the model building sessions. Vennix suggests the number of five participants in a group model-building process as the best size from his experience; however, each case needs to be dealt with specifically. The larger the size of the group the more structured the sessions need to be. In this research, the number of participants was chosen to be nine (Section 4.1.2, p. 167) and the sessions had to be highly structured. The group diversity according to Vennix (1996) is advantageous to the model's quality but might create more tension within the group. I agree with Vennix's conclusion- the diversity of the group in this research caused lots of tension and friction within the group especially with the CEO (Appendix C). Therefore, the facilitator has to be very skillful at problem solving when such tensions arise, otherwise, the process of building the model might fall apart.

During the third stage one has to decide whether to start with a preliminary model. As Vennix (1996) stated, usually a preliminary model is not available and that was also the case in this research. According to Vennix (1996), starting without a preliminary model is effective in terms of time because no interviews have to be scheduled. In the process of building the model, I used interviews before starting the meetings for two reasons: (a) to understand the problems of the firm and be able later to guide the group to build the initial model and (b) to be acquainted with the potential participants for the group-modeling process. It also helped me later on to get in touch with employees who were not part of the group and who were helpful in providing information and data.

Vennix's fourth stage of the group model-building process deals with the preparation of sessions. Mostly, I followed the guidelines as described in Section 4.1.4 (p. 168). On the other hand, I was limited when using the five essential roles encouraged by Richardson and Andersen (1995), Vennix (1996) and Andersen and Richardson (1997). In my study, the group participants were not interested in taking on a specific role. The sessions were scheduled according to Vennix' suggestions; however, there were several related issues that I found important to point out:

- a) In the first session I assumed it was important to explain and illustrate to the group what group model-building is and have them understand the general goal of these sessions and how the group modeling process is to be managed (Appendix A).
- b) Assuming that the members in the group have no system dynamics background, I deemed it important to introduce to the group, during the first meeting, the concepts of system thinking, system dynamics and explain what feedback loops are. In order to practice systems thinking, I also gave them some challenges concerning exponential growth and mental model challenges to work on at home (Appendix A).
- c) Since the group was larger than recommended (nine participants) I found it useful to hand out a conduct code which listed their commitments and expected behaviors (Appendix B).

- d) A feedback form was drafted and criticized by the group participants. The accepted one was used in all the sessions in order to be able to improve discussions and sessions (Appendix B). The feedback form included questions about the session's contents, its process and personal questions.
- e) Participation in a group building-model requires a high level of communication. I found it important to introduce to the group some concepts on better communication (Appendix B and Appendix C).
- f) Since the sessions were scheduled once every three to four weeks, I deemed it necessary to provide a summary of the previous session.
- g) Specifically for this firm, I found it important to discuss with the group the concept of "wants" – understanding what someone wants that helps her/him to act and imply a movement towards or away from it (Miller et al., 1997) (Appendix C). Other kinds of problems might need different insights and openness, since system dynamics by its nature requires many kinds of knowledge and understanding.

In general, although it is preferable to plan each session in detail, it is important to be flexible during each session, to listen to the participants' intents and desires as the participants are the facilitator's customers.

5.2.4 Modeling Process Learning Critique and Conclusions

In the role of a group model-building facilitator there is a continuous learning process. The facilitator is supposed to provide guidance to the group rather than being a participant. She/he has to be aware of the problem that is being tackled, but should concentrate on the process and structure rather than on the content (Phillips and Phillips, 1993). To facilitate successfully, requires separation of information, thoughts and emotions through the process of modeling. This kind of separation might sometimes create conflicts that are likely to harm the process and adversely affect quality outcomes.

The role of the facilitator cannot be fully predetermined and may have to be adapted according to the idiosyncrasies of the group. The diversity of the group members and their interrelationships as well as the facilitator's style necessitate the need to understand the group's life by being flexible and accommodating to the needs of the

group members (Phillips and Phillips, 1993). The facilitator needs to improve through a learning process that can turn him/her into a more mature and experienced guide who can fully understand the needs of the group members. The ongoing learning is a natural path that may lead to a better understanding of behaviors and issues that might arise within the group.

Assuming a continuous improvement and better experience through reflection and internalizing of the group's needs, the facilitator may use various tools to obtain important feedback from the group members in order to improve the modeling process. In the process of this research I deemed it necessary, as I explained earlier, to distribute a feedback form at the end of each session (Appendix B), and to discuss the results at the next session, learning what and how to improve the process. The following are the important issues I have learned from the group members' feedbacks:

- 1) Starting the first session with a long lecture (even if topics are important like explaining system dynamics) is boring for the participants, as they expect to discuss the problem (Appendix A).
- 2) The facilitator has to remember that the managers and the employees of the firm are his/her clients, and no matter what their attitudes, opinions or concepts are and he/she is supposed to serve them (Appendix C).
- 3) A meeting's schedule is very important but needs to be flexible and resilient. The schedule is valuable in the process of working with a group. Attention should be given more to the group participants rather than to the meeting program goals.

Being a facilitator is not the only task of the modeler. Building the model and suggesting the recommendations that lead to the policy changes require some knowledge of the main characteristics of the system. Even the best possible model created in such a process is useless if top management is not ready to listen and accept the results. It is therefore important to know whom exactly we are serving and who will follow up on the changes that are suggested as a result of the process. If those who have the ability to drive the required changes are not cooperating, there is no justification to keep on with the process.

Another important notion about collecting information should be considered while building the model. Measuring variables like stress requires the use of questionnaires. The modeler has to be sure that management will confirm the use of such questionnaires which require some time investment on behalf of the employees. More importantly, the questionnaire must be accepted by the management, in spite of unpopular questions. To view the impact of emotions (stress or satisfaction) on other variables like organizational effectiveness requires the modification of the questionnaire in order to see how the new behavior results from the change.

Last but not least, the model (as all models in general) is only an attempt to represent the reality. It is never reality, or as Sterman (2000) emphasized: “all models are wrong...all models, mental or formal, are limited, simplified representations of the real world.” (p. 846). In any case, our mind has its own peculiar mental model of the reality; therefore there are many difficulties and limitations involved in building an accurate model. I assume that any other researcher might come up with different results following the group modeling process for a different organization; however, the behavior of variables as a result of the relationships among them will most likely be the same.

5.3 Recommendations for Future Research

In closing the loop which started out with questions that arose as a result of reading various domains in the literature, I was driven to research the linkage among quality culture, employees’ health and organizational effectiveness for a specific firm. At the end of this endeavor, I state the contribution of this research, the recommendations for decision makers in organizations and recommendations for future research.

5.3.1 Contribution of this Research

This research provides a new holistic framework that focuses simultaneously on promoting organizational and employees’ outcomes assuming that a balance between these outcomes is in the best interest for both in the long-run. The framework (Chapter 3, p. 117) was built upon systems thinking theory and used the system dynamics approach. The system dynamics approach has enabled the understanding of the dynamic relationship among organizational effectiveness, employees’ health and quality culture.

This framework provides the basis for learning and for being capable to adapt to change as required by our present organizational realities.

As mentioned before, the notions of this research were obtained from the literature from various disciplines where it seems that certain practices and experiences converge when dealing with organizational effectiveness, quality culture and employee's health (for example: collaboration, long-run plans, etc.). My goal was to reveal the dynamic relationship among the various variables in the organization, linking quality culture, employee's health and organizational effectiveness, in order to contribute to the organizational knowledge and development. This research is action research built upon a case study. In reality, we can witness a huge variation among a large number of organizations, which might differ a lot from one to another. The place the research was done was chosen incidentally. The model was built by the group participants and eventually the findings show that the dynamic hypotheses based on existing literature were demonstrated with more complex relationships among the variables than were found in the literature. This enhances the internal validity, generalizability and theoretical level of the research (Eisenhardt, 1989). The dynamic hypotheses were formulated using the system thinking approach to illustrate relationships between variables from different disciplines. Through this research, the general conceptualization of organizational systems was enhanced, since the three constructs affect some of the complex organizational characteristics such as trade-off between long-term and short-term goals, the conflicts between objective and measurable outcomes and subjective outcomes, etc. Therefore, the results of this research have made it a generalizable one. The research includes detailed records about its context, including information about the physical environment, social factors and the process of group model building sessions. This will help other researchers to draw conclusions about the extent to which its findings might be generalizable to other situations (Leedy and Ormrod, 2001). This study enables the readers to extrapolate some specific applications, as long as the real situation is similar (if possible) to the situation of this research, including, for instance, the subjects, tasks, variables and the environment. In such a case, the researchers can simulate those applications as closely as possible (Chapanis, 1988). This opportunity is the result of the generalization of the research. On the other hand, Chapanis pointed out that there is no

way to measure similarity. The findings of this research can be applied over a wide range of situations since the three subjects that were studied are in the interest of all organizations and enterprises. The research also achieved generalizability because parts of each dynamic hypothesis are actually replications of studies that have already been done, with particular changes involving the systems dynamics approach. Replication is appropriate in the research, but the results also demonstrate new insights that are significant for a research to be a strong theory-building research (Eisenhardt, 1989).

Some limitations concerning generalizability according to Chapanis (1988) include the use of variable names like fatigue, stress, pressure or any other topic which does not necessarily show that they are equivalent. These kinds of variables are conceptual variables and cannot be studied directly. Chapanis argues that some conceptual variables may vary greatly. They might be measured differently, thwarting the attempts to generalize, although it seems obvious to be able to do it. Therefore, Chapanis (1988) cautions researchers to be careful in generalizing about conceptual variables: “Although it is tempting to assume that studies identified with a common key word all refer to the same phenomenon, in reality there may be little or no commonality among them” (p. 257).

In conclusion, this research adds to the incremental development of the study of the design of effective social and organizational systems, where the products and the services are created in a quality fashion, and individuals experience an environment that is conducive to their well-being.

5.3.2 Recommendations for Decision Makers of the Organization

This research demonstrates the importance of the leaders, the decision makers of firms, in leading a system with the understanding of the relationship among organizational effectiveness, employees' health and quality culture. As mentioned before, the decision makers' suggestions for improvement emphasized particularly the notion of having effective leadership which is considered essential for any organizational change and improvement. Most of the decision makers' efforts should be aimed at building quality culture in the organization, which includes among others: management based on facts in order to be able to understand trends, cause and effect, and interrelations among

variables which are too complex to be evident without such data collection and analysis (Delert et al., 2000; Gryna, 2001). Relating the long-time horizon as the preferred time horizon for the decision makers' and other members of the organization, the time horizon is important for planning and goal setting, which emphasize the commitment to quality. Also, the decision makers are supposed to build the right organizational atmosphere that welcomes changes and innovations without fear and stress. Leaders nowadays have to take into account the fact that the workplace is the place where the employees spend most of their time; therefore they have to create a workplace that is also a social system. Teamwork is an essential practice in building both quality culture and a healthy workplace. The decision makers should be committed to support a loosely controlled organization, where decision-making is shared throughout the organization and flexibility and autonomy are appreciated. Building an organizational culture that can stay in business and be effective compels developing technologies to create products and processes that meet customers' needs. Another lesson from this research about the decision maker's concern is the ability to listen. Listening is the most valuable competence for a leader, providing him/her with the capability to learn, understand, grow, develop and mature in order to create a quality culture atmosphere with proud, satisfied and healthy employees who are likely to feel committed to their workplace.

5.3.3 Recommendations for Future Research

This research process initially started from the notion that organizations are social systems. Viewing organizations as systems requires the use of interdisciplinary tools that are aimed at improving organizational and employees' outcomes. It is important in the future to conduct more research in the field in order to ascertain whether this particular theory is generalizable by using various cases that are intended to achieve the same relationships. In order to detail the recommendation for future research, I chose one of the Japanese TQM techniques: the "5W + H" method- essentially asking the following questions: What, Who, When, Where, Why and How? Future research that will answer these questions will contribute to the generalization of the findings of this research.

What?

In this research I have looked for a way to improve the way an organization is managed in order to survive in the long run by using the connection among three elements: organizational effectiveness, employees' health and quality culture. Each of these elements consists of a variety of components and dimensions. In this research, I considered organizational effectiveness only as it related to the production subsystem. As for employees' health, I chose to refer only to health problems that stem from stress. The quality culture dimensions were drawn on the basis of literature, mainly from research by Detert et al. (2000). Future research would have to challenge the concepts which are the basis of this study, namely using different definitions of organizational effectiveness, employees' health and quality culture, and examining their behavior as a result of their interrelationships. It would be important then to compare this research to a new one in order to learn about emerging findings and new approaches.

Where?

This research took place in a small packaging firm that has certain characteristics. Similar case studies should be performed in other kinds of firms taking into consideration their particular employees, environment and management. A comparative study using the stock and flow structures developed in this research then should be conducted as a starting point to examine the effects and implications of changes on the behaviors of the organization's variables. In addition, the systems' boundaries might be different in other cases. In this research the model includes only the production, the maintenance, the quality, the inventory and the personal subsystems. In other research, the system boundary might have to include such subsystems as administration, marketing and others, depending on the specific firm, in order to verify or refute the dynamic hypotheses this research has demonstrated.

Who?

The school of thought to which researchers belong might influence the study's outcomes. Therefore I recommend that researchers from varying backgrounds experience building similar models in order to learn whether the educational origin influences the interpretation of the results of the case study.

When?

This research took place at a time when the firm studied was having some problems. The recommendations for policy changes were not implemented and the model and its behaviors were not re-examined. In future research, I would recommend to find out whether the relationships among organizational effectiveness, employees' health and quality culture revealed in this study change under the different conditions: when all problems are solved, when new problems emerge, or when there are no problems at all.

Why?

This research was conducted after the emergence of problems within the firm. As mentioned before, it is suggested to conduct a new study while there are no apparent or specific problems in order to investigate the validity of these research results.

How?

This research was conducted by a single researcher. Collaborating researchers from different disciplines whose purpose is to build such a model and understand its behavior might prove to be more effective and could provide more insights and understandings of the relationships among organizational effectiveness, employees' health and quality culture.

In summary, this research is an attempt at understanding the linkage between organizational effectiveness, employees' health and quality culture. Further research should involve more researchers and examine more case studies in order to generalize the finding of this research and to deepen the understanding of system behavior as a result of the relationships among those concepts.